[illegible]

MOTION PICTURE
IN EDUCATION

[illegible]

[illegible]

[illegible]

5194

JOURNAL OF THE SOCIETY OF

MOTION PICTURE AND TELEVISION ENGINEERS

THIS ISSUE IN TWO PARTS

Part I, December 1951 Journal • Part II, Index to Vol. 57

VOLUME 57

July — December 1951

SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

40 West 40th St., New York 18

CONTENTS — Journal

Society of Motion Picture and Television Engineers

Volume 57 : July — December 1951

Listed below are only the papers and major reports from the six issues. See the Volume Index for those items which generally appear on the last few pages of each issue: Standards, Society announcements (awards, Board meetings, committee reports, conventions, engineering activities, membership, nominations, section activities), book reviews, current literature, letters to the Editor, new products and obituaries.

July

August

September

October

November

December

5194

Practical Application of High-Speed Photography in Business Machines

By WILLARD L. HICKS and ROBERT L. WRIGHT

Discussed is the use of a high-speed camera as a tool in the Company's Engineering Division. Motion of fast moving parts is easily plotted by the use of a special timing disc graduated to 0.001 sec. Through the use of negative film, film can be processed for study within two hours.

THE DESIGN AND PROVING of the light, fast-moving parts in business machine mechanisms has been a difficult and time-consuming job. Advances in this field, while continuous, have been obtained only at a high cost in time and labor.

In our study of the action of these mechanisms, we had been limited to the current instrumentation methods and to others which we improvised to record time and movement. But we had felt for some time that if we could slow down or actually stop the normal, rapid motion of parts under study, then our engineering work would be greatly simplified.

Five years ago our Engineering Group had a particularly perplexing problem which had been under study for several years and to which a number of solutions were submitted. The question was how could we choose the right one without extensive testing. A high-speed camera capable of exposing 3000 frames a second was procured and put to work on this problem. The camera quickly proved to the satisfaction of engineering the correct solution.

Presented on May 2, 1951, at the Society's Convention in New York, by Willard L. Hicks and Robert L. Wright, Standards Div., Burroughs Adding Machine Co., 6071 Second Ave., Detroit 32.

An entirely new tool had been added to our engineering analysis. However, it was a problem to sell this method to all of our development groups. Today, our high-speed camera is very much in demand and our camera work has developed to the point where we take pictures in the morning and have them ready for analysis the afternoon of the same day.

The high-speed camera like any other analyzing equipment can be used only to study or determine trouble if you know where to look for it. The mere shooting of pictures generally results in only exposing film of no value. If a machine is missing operations, you will have only approximately one second to film that operation and may have to shoot more than one roll of film to pick it up.

Adding machine operations are rather complex. Let us briefly outline one of our typical operations so that our application of high-speed photography can be more readily understood. In the hammer section of an accounting machine, spring-energized hammers are used for printing on rubber platens or printer rolls. In this operation we are concerned with the initial release of the hammer, its acceleration and final velocity, the rebound of the hammer and type from the printer roll, the deflection and vibration of the magazine spring

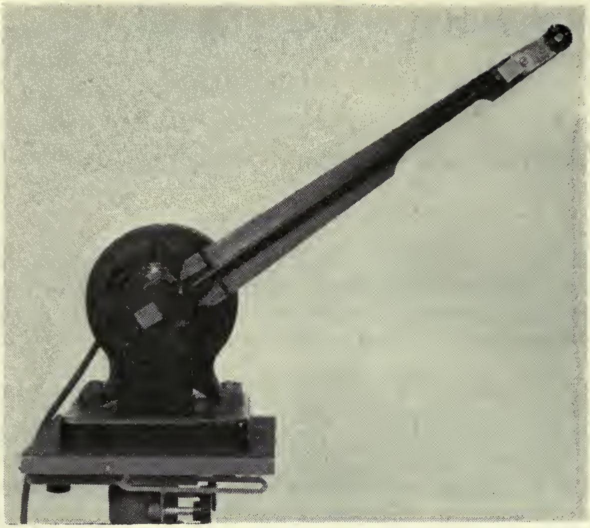


Figure 1

that returns the type, the time of reset for a repeat stroke of the hammer with relation to the complete machine cycle, the motion of the hammer on rebound, and the degree of certainty of the pickup or latching of the hammer in the cycle.

Now let us consider time in this operation. This particular machine is operating at 128 printing strokes per minute, or less than one-half second per stroke. However, the hammer itself fires and prints in 0.008 sec and is picked up into a latched position in a total of 0.130 sec.

In other mechanisms we have found that actual layout displacements are increased due to elastic bending while in motion. In some cases such overthrow movements cause machine lockups, wrong operations, and fatigue failures.

Time studies, such as those of time required for specific mechanical operation, accelerations, and velocity are made with a timer (Fig. 1) developed by Burroughs for our use. This timer consists essentially of a 1-in. disc graduated to 0.001 sec, revolving at 3000 rpm attached to an 18 in. long shaft which can be rotated in two planes. The timer is placed in the field of every picture taken with very little sacrifice of field. Very precise timing can be made while running the film through a time study projector, a frame at a time if necessary.

Accelerations, velocities and deflections determinations are made by enlarging the picture on a screen through a time study projector. The picture enlargement factor can be obtained by photographing a scale in the field of the parts to be studied. Displacement can then be measured directly. Acceleration and velocity are determined by plotting time against distance; however, it is necessary to center each frame, on the screen or paper, on known reference points.

Where we have machine cycles of less than one second, it is sometimes necessary to incorporate microswitches to start the camera. The microswitches are attached to, and are directly driven by, the mechanism to be photographed at a required instant in the machine cycle. It must be remembered that a further allowance of approximately 50 ft of film may be required to allow the camera to reach its maximum speed.

The camera equipment is extensively used for the following applications:

1. To prove plate models of new developments before breakdown testing and final design.

2. Improve operation of existing machines.

3. Study the effects of proper and improper adjustments.

4. Establish test fixture comparisons of machine movements for correlation in testing.

5. Determining the lag or overthrow of cam-driven parts.

6. Study the flow of metals in shop cold working operations.

7. Study the actions of springs in motion.

A typical lighting setup used at Burroughs involves concentrating the light beams of four RSP #2 Photospot Lamps on the subject, with the lamps approximately one foot from the subject. A lens opening of $f/5.6$ and maximum picture speed of 3000 frames/sec will result in good exposure on Kodak Super-XX Negative Film. If a greater depth of field is required, 750 R Lamps may be used so that ample exposure can be obtained at the same camera speed, while at the same time smaller lens openings can be used, thereby increasing the depth of field.

Figure 2 is an example of a lighting setup for the carriage tabulation picture which also shows our camera equipment and subject. In this exposure, two lamps (RSP #2) placed approximately one foot from the subject were used. The lens opening was $f/8$. A 50% rheostat setting equivalent to approximately 1500 frames/sec was used.

The camera equipment is a standard Eastman Kodak Co. Type 3, High-Speed Camera with a standard 63-mm, $f/2.7$ lens.

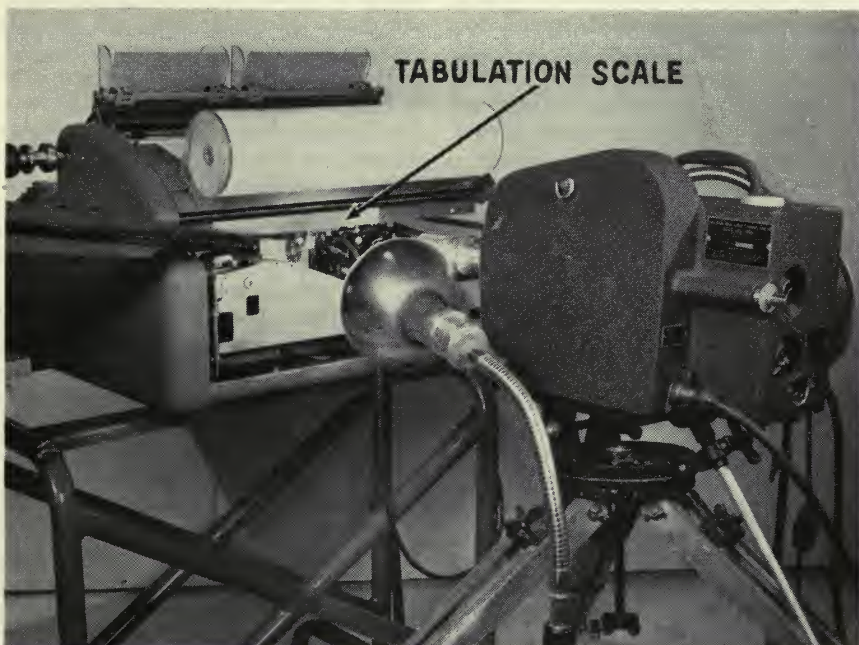


Figure 2

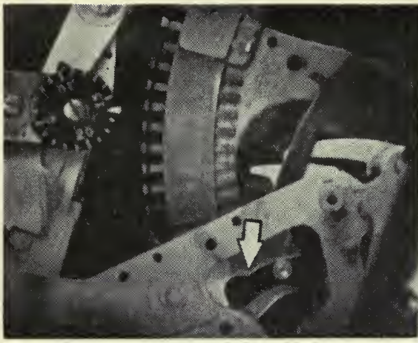


Figure 3

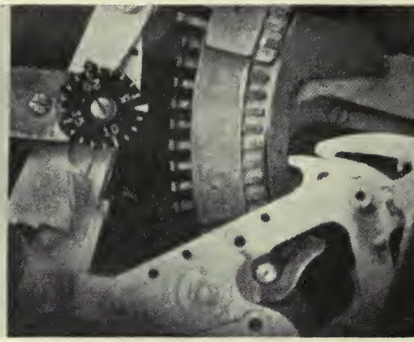


Figure 4

Recently, we obtained a new Kodak Cine Ektar 25-mm, *f*/1.9 lens which is designed to increase our present 63-mm field width by $2\frac{1}{2}$ times. This lens will greatly expand our present field coverage.

Eastman Super-XX Negative Film is used in taking these pictures, which has certain advantages for our use. Its ease and time involved in developing is a great asset (approximately one hour). Enlargements for detailed studies for record and report purposes can be made directly from the negative film. Then, of course, there is a saving on the price of the film. To highlight details, parts are painted with a flat-white, quick-drying, heat-resistant paint.

Type Hammer Printing

Figures 3, 4 and 5 represent three pictures taken at 2000 frames/sec of a critical printing action, the solution of which was greatly expedited through the use of high-speed photography. The cam slot indicated by the arrow shown in Fig. 3 represents the portion of this action which gave us our trouble. In Fig. 3, the spring-driven driver roll follows the upper cam surface and propels the hammer forward. This cam surface is a portion of the hammer shown by the arrow. As the roll follows this cam surface into the well, it is necessary that there be sufficient clearance between the relatively stationary roller at this instant after firing and the cam projection lip indicated by arrow (Fig. 3) which is called the cam velocity high-point. One thirty-second of an inch less clearance on occasion will cause the free hammer to rebound into the type and print a second time. Figure 5 arrow shows this condition if you will visualize this section with a further build-up of $\frac{1}{32}$ in. on the upper cam face. Figure 4 shows the normal position of the drive roll on printing.

The time displacement curves shown in Fig. 6 were plotted from this action. The hammer displacement was obtained by plotting the travel of the hammer type contact face on paper shown by small arrow in Fig. 5. It is necessary to realign the picture between frames by centering on ***established picture reference points*** to compensate for machine movement while in operation. The actual displacement can be obtained by dividing the projected screen displacement by the enlargement factor. The enlargement factor can be obtained by dividing the enlarged part dimension by the actual part size. The time is read directly from the timer.

The curves A "original design" and B "corrected design" (Fig. 6) were plotted frame by frame. These curves indicate we lost little in velocity through the reduction of the cam face (Fig. 3) at curve point C. Point D graphically indicates adequate drive-roll clearance

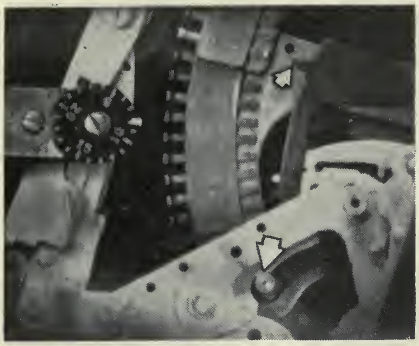


Figure 5

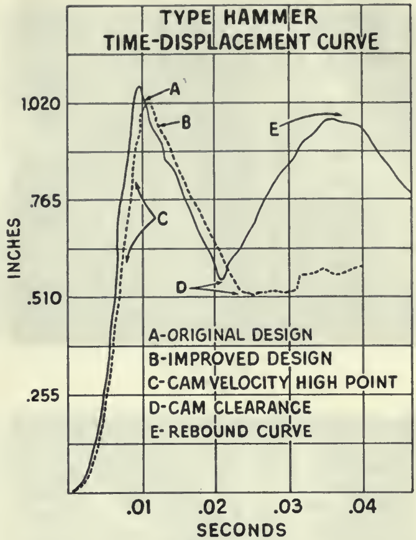


Figure 6

between the cam face and the roll. Notice the sharp hammer rebound shown by E of curve A. Very little hammer rebound is occurring between the hammer and the drive roll as shown in curve B. In the picture represented by curve B, the height of the rebound is approximately 0.045 in. under the first displacement. While this is under the amount of rebound necessary to cause a double print, the tendency to double print coupled with machine vibration frequency would further magnify this rebound. Consequently, through the correction of the cam slot and further testing, we were able to eliminate completely this difficult problem.

Simpler time-displacement plotting can be obtained by mounting simple reference points on the machine or mounting a direct reading scale as shown under the carriage tabulation example. Occasionally, abnormal actions are unexpectedly revealed during film study. In such cases, even though reading scales were not induced, the information for plotting can still be obtained by improvisation. Many curves have been plotted of this action, involving changes in hammer balance, hammer weight and spring force.

Another similar type-hammer printing section is shown in Figs. 7, 8 and 9. In this example the type magazine is exposed to show a 0.020 in. diameter music wire hair spring. This spring is used to restore the type to a normal position after printing. The hammer and type are highlighted with white paint; the spring blackened with carbon. The camera speed was 3000 frames/sec.

The three pictures shown are not consecutive frames, but are three of six frames embracing a cycle of 0.002 sec.

In Fig. 7 the second hammer has driven its type, while the first hammer is about to contact its type. Figure 8 shows that the first hammer has now driven its type ahead of the hammer. Note that the type shoe is driving the hair spring. Figure 9 also shows that the hammer has caught up with the type. Note that the hair spring is now out of contact with the type shoe.

The timer reading of 0.006 (Fig. 7), from 0.008 as shown in Fig. 9, represents a difference of 0.002 sec which is the time required for this printing action. These pictures were primarily used to study the whip action of type hair springs, which was so fast that our camera speed of 3000 frames/sec was not quite fast enough.

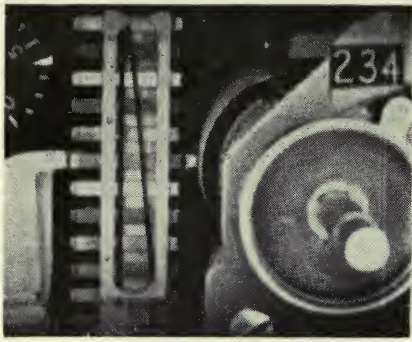


Figure 7

Figure 8

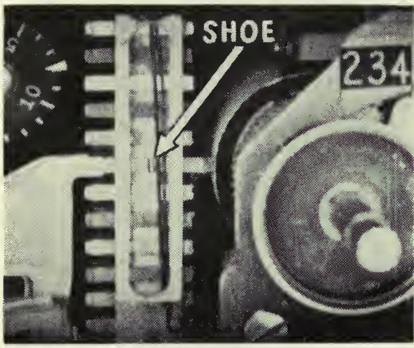


Figure 9

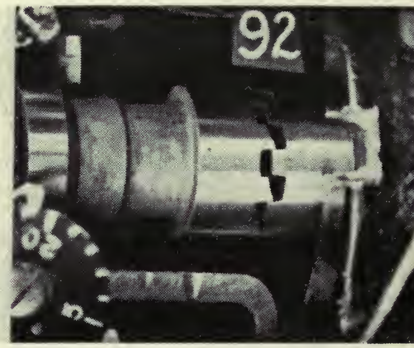


Figure 10

Multiple-Tooth Engagement Drive Clutch

In this particular application, the clutch is required to engage once for each complete machine operation. This clutch is turning at approximately 130 rpm. We had experienced some trouble with a loss of machine operations, caused by the clutch not being completely engaged at the beginning of the machine stroke. At 180 degrees of rotation of the clutch, the machine load reverses while the clutch is still rotating in the same direction. This machine reversal point removes the tooth engaging pressure, which occasionally disengaged the clutches.

A high-speed picture taken at 1500 frames/sec through an exposed housing assembly indicated that this trouble was resulting from a point-to-point tooth engagement as shown in Fig. 10.

Figure 11 indicates a desired tooth engagement position under the original design. It will be noticed that the left side tooth faces are cut at an angle to induce positive engagement; but still, occasionally improper point-to-point tooth engagement resulted (Fig. 10).

Figure 12 shows a helper pawl in position. This pawl prevents point-to-point tooth engagement by bearing against the entire face of the meshing sector. On rotation of this meshing sector, the pawl is displaced to allow complete engagement of the clutch tooth. In this instance high-speed photography helped us to eliminate this problem and to devise a positive method for insuring proper engagement.

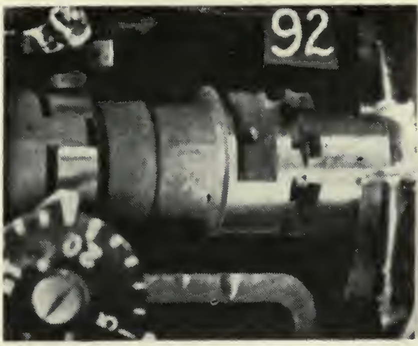


Figure 11

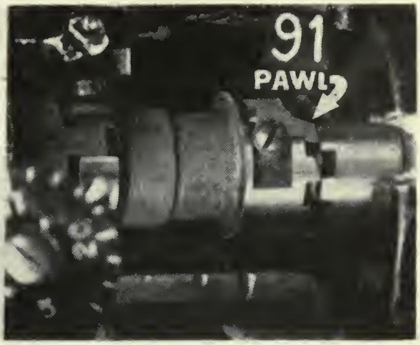


Figure 12

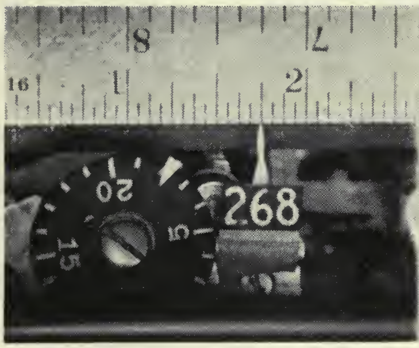


Figure 13

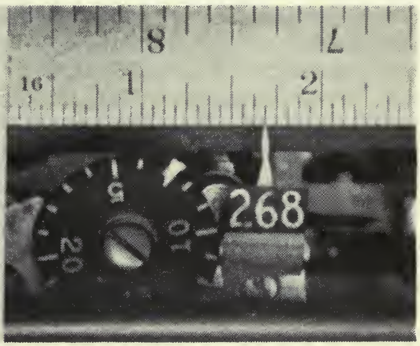


Figure 14

Carriage Tabulation (see Fig. 2)

Briefly this mechanism establishes a desired stopping position for indexing columns of figures on printed paper. In this machine-driven operation, we are concerned with various carriage weights, carriage velocity, friction clutches and friction breaks to reduce the carriage speed, all of which are timed together in the machine cycle and brought to a stop position through the action of a spring operated bumper mechanism.

Figures 13 and 14 represent our method of plotting a displacement-time curve as shown in Fig. 15. Pictures were taken at 1800 frames/sec. A steel scale is attached to the carriage with a fixed reference point. An examination of these Figs. 13 and 14 indicates a time change of from 0.0023 sec to 0.0073 sec for $\frac{1}{16}$ in. of displacement. This represents .005 of a second for the time required to travel $\frac{1}{16}$ of an inch. In this manner the curves shown in Fig. 15 were plotted. These curves were plotted

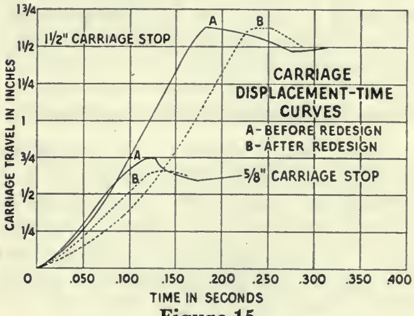


Figure 15

for $\frac{5}{8}$ in. and $1\frac{1}{2}$ in. carriage tabulation stops.

The carriage displacement-time curves represent two conditions, Curve A "before redesign" and Curve B "after redesign." The changes basically affected the clutch and brake. The carriage weight and tabulation stops were picked to represent the most critical conditions which were determined from previous picture variations. The carriage is traveling to the left, at the $1\frac{1}{2}$-in. carriage stop position, the curve represented by curve A clearly shows that more energy is required to stop the old design than the new design established by curve B. The curve A also shows a definite rebound and overthrow in the spring bumper on the right side, demonstrating that this bumper absorbed more energy. The overthrow in the left side spring bumper is very nearly equal. In the case of the $\frac{5}{8}$-in. carriage tabulation stop, a greater amount of bumper energy absorption is required in the old design versus the new design. The overthrow in the left side bumper is greater and overthrow also occurs in the right side bumper. It is interesting to note that the curves shift to the right in the changed design, indicating that a longer total time is required to reach the first bumper stop. Other changes have been made to further improve this example.

Timer Calibration Method (see Fig. 1)

The timer consists of an a-c motor running at 3570 rpm and a one-inch timing disc with 0.001-sec graduations up to 0.020 sec per revolution of the disc. A reduction gear train was used through a long arm to drive the timing disc at 3000 rpm.

In order to determine the accuracy of the above-mentioned equipment, the following procedure was followed:

1. A Strobotac (General Radio Co.) was calibrated for 3000 rpm against a 2-pole synchronous motor at a line frequency of 60 ± 0.02 cycles.

2. The speed of the timing disc was then checked against the calibrated Strobotac at a line frequency of 60 ± 0.02 cycles and the speed was found to be 2992 rpm. This represents an error of 0.267% below 3000 rpm.

3. Because our line frequency has been known to vary from 59.5 to 60.5 cycles, these frequencies were then used to obtain the maximum and minimum timing disc speeds, again using the calibrated Strobotac for our speed determination. The values obtained were 2982 rpm at 59.5 cycles and 3007 rpm at 60.5 cycles. These speeds represent an error of 0.6% and 0.233% below and above 3000 rpm.

4. The timing discs were calibrated using the following formula:

$$\frac{60 \text{ sec/min}}{3000 \text{ rpm}} \times 1/20 \text{ rev./grad.} = 0.001 \text{ sec.}$$

The time interval between graduations at 2982 rpm is

$$\frac{60}{2982} \times 1/20 = 0.001006 \text{ sec}$$

and at 3007 rpm is

$$\frac{60}{3007} \times 1/20 = 0.0009977 \text{ sec.}$$

Therefore our accuracy is $0.001 \text{ sec} \begin{array}{l} + .6\% \\ - .23\% \end{array}$

Direct line circuit overloads do not affect the timer motor. This was checked by a Strobotac.

This camera is not nearly as complicated as one would think, and a basic operating knowledge of the camera can be readily acquired by anyone qualified for design and production research work.

It is surprising, even in pictures, how much additional information can be gained by subsequent viewing of the same picture.

In conclusion, we have found that this application of high-speed photography enables us through actual pictures to analyze quickly mechanical problems and arrive at proper solutions.

Practical Use of Iconoscopes and Image Orthicons as Film Pickup Devices

By K. B. BENSON and A. ETTLINGER

At the present time, both iconoscopes and image orthicons are employed in monochrome television broadcasting for transmission of motion picture film. The theoretical considerations of such operation have been covered quite thoroughly in the literature, while the many practical problems have received very little attention. A discussion of the correlation between the basic theoretical problems of television motion picture film pickup and their practical solutions as presently employed in television broadcasting is given.

FROM A PICTURE and sound reproduction standpoint, television film transmission should equal in quality live programming, just as in aural broadcasting recorded playbacks can be indistinguishable from direct pickups. Actually the development of the image orthicon camera for direct pickup has progressed so fast that the majority of the programs recorded on film do not equal in quality the best live pickups. This situation is further aggravated, particularly in the case of the new television stations, by the fact that more emphasis is often placed upon studio or live pickups, even though a major portion of a station's more important program material may be reproduced from film.

As for the problem of raising the standards of television film reproduction, there are two roads to follow: one, the improvement of presently used equipment and operating techniques; and two, the introduction of new types of equipment and methods of film transmission and pickup. We shall first discuss a few of the problems associated with the operation of the iconoscope, the tube currently used for film pickup at the majority of this country's television stations, and then we shall describe the problems encountered with one of the more obvious approaches to new methods of film pickup, the use of the image orthicon.

The iconoscope operating problems may be broken down into three categories: (1) the proper operating conditions of the pickup tube; (2) the treatment of the associated video circuits; and (3) the operating techniques for maximum picture quality.

Figure 1 shows the transfer characteristic of the 1850A iconoscope for both continuous illumination and for pulsed illumination such as is used for motion picture film pickup. The figures of illumination for this latter curve have been corrected by a 5% duty-cycle factor

Presented on May 1, 1951, at the Society's Convention in New York, by K. B. Benson and A. Ettlinger, Columbia Broadcasting System, Inc., 485 Madison Ave., New York 22, N. Y.

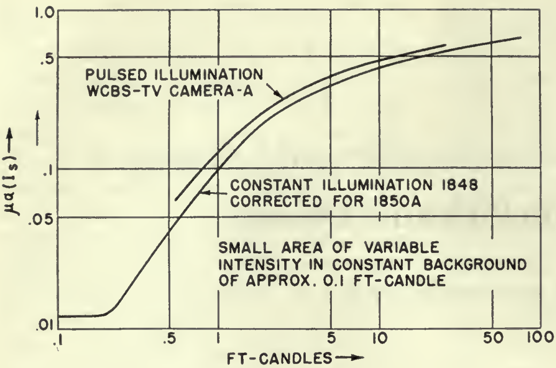


Fig. 1. Transfer characteristic of the 1850A iconoscope for both continuous illumination and for pulsed illumination.

to average values so as to correspond to values for the steady-state curve. It is readily apparent that above a value of 20 to 30 ft-c, the already low value of gamma is further reduced. This may be interpreted to mean that the tube will produce only a minor variation of signal output for a rather wide range of film densities. Hence, such operation will invariably result in serious white compression. Therefore, if an iconoscope is in good condition and used with films of normal densities, it should be unnecessary to employ any excessive illumination from the projector. In fact, in practice a light level such as is produced by a gap lamp machine or a 750- to 1000-w incandescent machine with a reasonably fast lens has been found ample. Any higher value will usually cause some additional white compression at the expense of a negligible signal increase. Thus, if it is found that abnormally high light levels are required to obtain a satisfactory signal-to-noise ratio, either the iconoscope is producing too low a signal output to be of any further use or the preamplifier is inadequate with regard to noise factor or overall gain.

Attempts have been made to correct, by electrical circuits of nonlinear amplitude characteristics, the white compression or low gamma of the iconoscope tube. However, two serious difficulties are encountered. For one, the increased gain for highlight signals produces not only an increase in the highlight signal but an increase in the noise level. This increase in noise level in the highlight area has been found to be quite objectionable in the reproduced television picture. Secondly, the accentuated variation in white levels resulting from expansion of the highlight signals considerably complicates the task of the video control technician, and his inability to cope with such changes frequently results in unsatisfactory television reproduction of the film picture.

The correction which is desired of the transfer characteristic of the overall film exposure, development and playback process can be obtained by the use of the negative film for the iconoscope pickup, rather than a positive print. In this process, to produce a positive image upon the viewing tube, the video signal may be reversed in polarity in the film camera video amplifier circuits. Both calculations and measurements show that the resultant transfer characteristic not only provides amplitude expansion of the picture highlight signals, which corrects for the compression of the iconoscope and recording process, but, in addition, provides a little useful shadow expansion. Further, since spurious signal effects such as edge flare appear black rather than white, they are not apparent to the viewer.

The practicability of such a method of transfer characteristic correction has

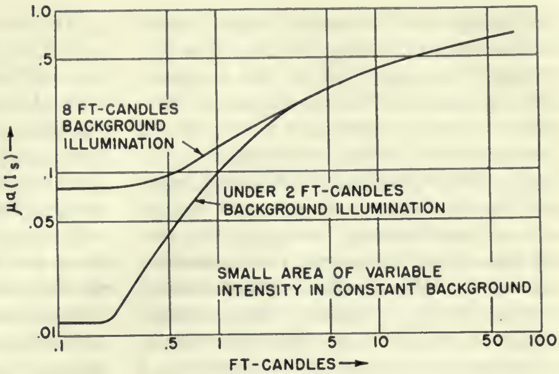


Fig. 2. Iconoscope transfer characteristic for two different levels of background illumination.

been verified by the success of its extensive use at CBS for the release in New York of television recordings of feature Hollywood programs. Using 35-mm negatives with an iconoscope for pickup, CBS has obtained picture quality which compares quite favorably with that of live studio transmissions.

Figure 2 again shows an iconoscope transfer characteristic, but in this case for two different levels of illumination. It can be seen that the signal output drops with increased average light level, assuming the maximum and minimum film densities have remained the same. Thus, in order to maintain as high a signal level as possible, and an accompanying high signal-to-noise ratio, the spurious light level upon the mosaic should be maintained at a minimum and as large a mosaic area scanned as is possible. Consequently, the edge light should be a narrow band sharply focused upon the extreme edges of the mosaic; the back light and iconoscope should be masked whenever necessary to direct the light to the glass envelope and not upon the mosaic; and from the film-production angle, exceptionally high key techniques should be avoided. Since chromatic aberrations exist in the iconoscope glass, color filters limiting the back- and edge-light emission to a spectrum corresponding to the peak sensitivity of the pickup tube will further reduce the spurious light reaching the mosaic. In addition, similar optical filters applied to the projector light beam will improve the fine detail contrast of the reproduced picture. In fact, in many cases such techniques will produce as much as 50 lines improvement in detail.

Figure 3 shows the spectral response of the iconoscope and of a filter suitable for the above use. It is apparent that while the 1850A's response peaks at about 460 mμ, there is still a fair degree of sensitivity in the red and infrared regions. Such radiation from the film projector can be removed quite thoroughly by a simple glass filter.

Aside from the iconoscope itself, of prime importance in obtaining the best possible reproduction of film is the noise factor of the low-level amplifier stages

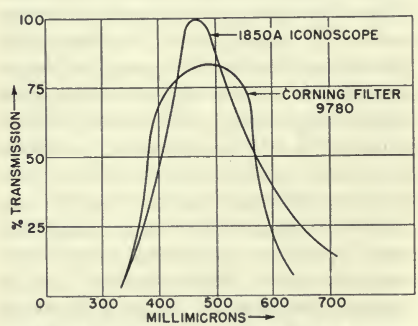


Fig. 3. Spectral response of the iconoscope and transmission of a filter suitable for improvement of detail contrast of reproduced pictures.

following the iconoscope signal plate. Unfortunately, in practice the major portion of the noise, both of the fine-grain shot type and of the low-frequency type, from vibration and hum occurs in the vacuum-tube video amplifiers, specifically those operating at the lowest signal levels. Such low levels occur at the first stage, and the stage following the conventional high-frequency compensation network. The transfer characteristics shown in Fig. 1 indicate that a signal output in the order of 10 to 40 mv may be obtained under normal operation. A similar level will exist after compensation. A triode preamplifier, such as a 6J6, 6J4, 6AK5 or 5654, operating at high transconductance and low plate current will give good results. The iconoscope signal-plate output lead should be small bare wire in order to reduce stray capacities to a minimum. Shock mounting should be applied to the amplifier tube to reduce microphonics. As to the compensated stage, here again shock mounting should be employed. Since input capacities are not too important in this stage, the 6BC6 with its high transconductance and good stability has been found to give excellent results. One other likely candidate, the 6AH6, has proven to be unsuitable because of excessive heater-to-cathode leakage. Shielded filament leads for all low-level stages will greatly assist in the elimination of any stray low-frequency interference. All tubes, except the two abovementioned low-level stages, should be operated so as to be capable of considerable voltage swing without compression. Frequently, certain operating conditions may cause spurious signals to exceed the picture information and, if good conservative design has not been employed, such operating conditions cause overloading of the video amplifier and resultant compression of portions of the video signal. Needless to say, with such low levels of signal all shielding and grounding should be very thorough and complete.

From the operational standpoint, there are three adjustments which may mean the difference between excellent film reproduction or just mediocre results. These are: (1) iconoscope beam, (2) edge light, and (3) back light. All three are interlocking in adjustment and if properly set up will be satisfactory for a wide range of films and will greatly reduce the necessity of continual readjustment of other controls during a pickup. The beam should be set to a point where a further increase will produce only a minor improvement in signal-to-noise ratio. The absolute value of this setting will depend directly upon the excellence of the video amplifier. An excessive beam will cause an objectionable graininess in the picture plus serious variations in shading and edge flare. Once the beam is set it will be satisfactory for almost all operation. Above all, it should not be used as a gain control; all video level adjustments should be made with the video gain control. With a proper beam adjustment, the edge light may be set to a level which eliminates all flare with a dark scene projected upon the mosaic. Best results over a wide range in film quality will occur when the maximum possible area of the mosaic is scanned and a narrow, intense band of edge light is employed. To complement this adjustment, a setting of the back light will be found which will cause a reduction of the application pulse. Any additional back light will cause excessive application pulse and poor field storage upon the mosaic.

Investigation of the Image Orthicon

Up to the present time, the use of the image orthicon, rather than the iconoscope, for film transmission has been investigated by relatively few television broadcasters. The reasons for this limited use have been twofold: first, taking into consideration the initial cost and the average useful life of the two tubes, the hourly cost of image orthicons is found to run about three times that of

iconoscopes; and second, to realize maximum picture quality, rather extensive mechanical modifications are necessary on presently available television projection equipment to adapt it to image orthicon use. However, the increased life of the newer image orthicons has reduced the operating expense somewhat and this factor, plus difficulties of procuring good iconoscopes, has made the use of the image orthicon for film pickup considerably more inviting.

The major installation problems encountered with an image-orthicon camera chain are those concerned with the modification of the television projector, since most of these units are designed for the relatively high intensity and large-image operation required by the iconoscope. The basic requirements for image-orthicon application are: (1) an image of readily adjustable size from approximately 1.2 to 1.6 in. in width; (2) a throw of about 14 in.; and (3) an illumination level of from 1000 to 5000 times lower than that normally used for the iconoscope. Methods of satisfying these requirements are discussed in greater detail below.

The reduced image size may be obtained by extending the mount of the usual 3- or 4-in. projection lens about 2 in. and focusing the image directly upon the image-orthicon photocathode. Such an extension of the lens mount must be of exceedingly rugged construction; otherwise any vibration of the projector will result in a loss in accuracy of registration of the small image upon the tube. In fact, experience has indicated that the problem of instability of any longer extensions prohibits the use of a lens of greater focal length than 4 in. This limitation of throw rules out the use of the usual method of diplexing two projectors through mirrors into one camera. If more than one projector is to be used with one camera, a turret camera mount has proven to be a very practical solution.

The optical focusing arrangement in the standard image-orthicon camera provides a useful method for adjustment of picture size upon the photocathode. The arrangement should be such that the corners of the projected image slightly overlap the periphery of the photocathode when the image-orthicon tube is at the end of the focusing range. As the tube is moved forward and the lens refocused, the projected image will become progressively smaller until the entire image is within the photocathode area. Thus, the image size can be easily readjusted to match any reduction of scanning raster size necessary as the image orthicon ages. The change in the position of the projection lens often causes an uneven light distribution over the resultant image which may be corrected by removal of one of the condenser lens elements. Since this modification increases the focal length of the condenser system, it may be necessary to insert a diffusing glass in place of the eliminated lens in order to remove an image of the projection lamp filament.

Several approaches to the problem of reduction of light intensity are possible. Some light will be lost in the basic modification of the condenser lens. In addition, since the projection lens will not be used at its designed magnification, some loss in corner resolution will occur. This loss may be corrected, and at the same time a light reduction obtained, by stopping the lens down about $f/8$ or $f/11$ (an opening of about $\frac{3}{8}$ in.). These two expedients provide a reduction factor in illumination of 100 or so. In the case of the incandescent projector, a further reduction in the order of 10 to 20 can be very easily provided by the substitution of a 50-w or smaller projection lamp. If the efficiency of the condenser lens system has not been greatly impaired, a 6-v, 3-amp, prefocused unit is an even more convenient means of reducing the light intensity.

Because of the limited contrast acceptance of the image orthicon, compared to the contrast range available from motion

picture film, it is essential that a means be provided for readily available operational control of the projector light level. If a small incandescent lamp is employed, a simple control consists of a series rheostat in the lamp circuit. Gap-lamp, pulsed light projectors, however, present a more difficult problem in light control as well as in light reduction. One successful answer consists of a combination of a neutral density filter to provide a fixed value of light reduction, and two Polaroid filters for a variable element. The degree of reduction obtained from the Polaroids may be varied by rotation of one filter in its own plane through selsyn control from the operating position.

Concerning the image-orthicon camera, the only absolutely essential modification is the provision for reversal of the direction of vertical scan and, if an optical diplexing system is contemplated, reversal of the horizontal scan. An additional and very desirable modification is the removal of the scanning controls (size and centering) to the camera-control position, so as to provide the operator with a means of conveniently compensating for differences in film framing and camera scanning drift. In the event that transmission of negative film may be required, a switch and circuit for reversal of video-signal polarity is also required. The quality of the transmission of negative film through an image orthicon film chain is usually poor, however, and consequently such operation should be used only in an emergency.

From an operation standpoint, it may first appear that the image orthicon would require fewer operating adjustments than the iconoscope because of its freedom from shading difficulties; however, since electron redistribution effects cause the transfer characteristic of the image to vary over a wide range as average light level and distribution of scene brightness change, it, too, requires a frequent readjustment of controls. Although this factor is not very troublesome with carefully processed film having a narrow density range, with the average film it may be almost impossible to avoid drastic shifts in signal level or sudden complete saturation at either end of the transfer characteristic. If such changes can be controlled, it will be found that the image orthicon will produce an apparent higher definition than the iconoscope. This is because this electron redistribution, in effect, creates an expanded transfer characteristic in areas of fine detail.

The constant low gamma of the iconoscope results in a signal level reasonably independent of variations in average film densities, while the image orthicon is quite critical as to such variations. Thus, the image orthicon does not have as universal an application to film pickup as does the iconoscope, but for films having a low density range (in the order of 1.0 to 1.5) the image orthicon is capable of producing a picture of considerably improved definition and gray scale over that from an iconoscope, and at an operating cost not greatly in excess of the latter.

Experimental Utilization of TV Equipment in Navy Training Film Production

By J. S. LEFFEN

An acceptable training film can be rapidly produced by utilizing television cameras and a video recorder to combine shooting and editing. High equipment costs and relative immobility of equipment limit application to large-scale producers except in cases where speed of production is of paramount importance.

THE NAVY has long felt the need for a rapid method of producing training films for immediate utilization in times of emergency. Conventional techniques have produced a high-quality product in a reasonable time and have been entirely adequate for peacetime operation. In times of emergency, past experience has shown that new equipment is frequently produced and in use in the fleet before the training film on its operation arrives on the scene.

In an effort to speed up production, several experiments, including simultaneous multicamera coverage, have been attempted with varying degrees of success. The Naval Photographic Center's successful experimentation with kinescope recording aroused an interest in the possibility of utilizing television equipment in motion picture production.

It was believed that an acceptable continuous "edited" negative of a ten-minute training film sequence, complete with titles and effects, could be produced by use of two or three camera chains, a camera switching and effects unit and a kinescope recording unit. By the addition of standard double system sound, title music, narration, dialogue and sound effects could be added. The actual production would then consist of rehearsal, shooting and processing, completely eliminating the editorial phase. While it was realized that use of present television scanning standards would inevitably lead to some sacrifice of pictorial quality, it was believed that in view of the probable saving of time, this loss would be acceptable for some types of subject matter.

Presented on April 30, 1951, at the Society's Convention at New York, by Lt. Comdr. J. S. Leffen, USN, U.S. Naval Photographic Center, Naval Air Station, Anacostia, D.C. The opinions and assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

A survey of available commercial equipment disclosed that the products of several manufacturers would probably fulfill our requirements. One manufacturer (General Precision Laboratory of Pleasantville, N.Y.) offered to make a two-camera chain, a camera switching unit and a kinescope recording unit available for experimentation. Noteworthy features of this equipment are: small size of the camera units, use of picture tube blanking rather than a mechanical shutter in the video recorder and addition of a "gamma correction amplifier" in the video chain of the recorder unit.

Since a project was on the books which seemed a natural for the proposed type of production technique, the offer was accepted and script writing commenced. In view of the probable difficulties to be encountered with wholly unfamiliar equipment, it was decided to keep the script as simple as possible. Subsequent events proved this a wise decision.

The equipment, upon arrival, was found to have been severely handled in shipment. Several days were spent in making temporary repairs and adjustments. This rough handling may have also been partially responsible for the continuous minor difficulties and failures which plagued the remainder of the experiment.

The manufacturer's experience in video recording had been primarily in production of a positive by photographing a negative image on the kinescope. It was originally planned to make extensive sensitometric tests with varying camera settings, video gamma, exposure and gamma of development to get the best possible negative. The initial loss of time due to equipment damage made it necessary to seriously curtail these tests and they were abandoned completely as soon as a usable negative was produced. The emulsion stock used was Eastman Kodak Company #7373, a sound recording stock. This was in line with the film and equipment manufacturers' recommendations for kine recording for subsequent retelecast. It is possible that another emulsion might have been more suitable for the ultimate production of projection prints.

The video equipment was set up with the cameras on the sound stage, the camera control, switching and monitors in the stage projector booth which overlooks the stage and the video recorder in a room remote from the stage. The camera control operators and director, who operated the camera switching unit, were stationed in the stage projector booth. Two-way headset communications were available between the director and the assistant director and cameramen of the stage.

The sound mixer was stationed in a monitor room on the second deck overlooking the stage. From this position, he controlled the re-recorder used for title music and rode gain on the narration. An "on the air" picture monitor was provided at this station. In this temporary installation, it was necessary to leave the stage and projector booth doors open to provide passageway for cables. This resulted in a substantial increase in ambient noise level. To combat this, the narrator was provided with a microphone on a chest plate. This resulted in an improved signal-to-noise ratio and greater freedom of action. It was hoped that the remainder of the ambient noise would simulate that of the scene depicted.

Completion of repairs, sensitometric tests and setup required so much time that it was necessary to commence rehearsals simultaneously with indoctrination in equipment operation.

So little time remained to use the equipment, that it was decided to dismiss technical defects such as poor sweep linearity, improper view-finder alignment and less than optimum lighting and print quality as factors

which could be corrected if time were available, and to proceed with rehearsals and shooting.

With the commencement of rehearsals, additional difficulties were encountered. It was discovered that the detents on the camera-lens turrets were not strong enough to position positively the ten-inch lenses. Since these lenses could not be used, more camera movements were required than had been originally scheduled.

In all, a total of fourteen hours of rehearsal and shooting were required. While this may seem inordinately long, it should be remembered that neither the director nor the cameraman had ever used television equipment before. The director was performing the dual job of director and technical director. With the exception of the narrator, no professional acting talent was employed.

The original objective of producing a continuous negative in one take was not quite achieved. As time ran out, one almost perfect take was made and only enough time remained to make two short pickup shots.

Although this experiment was too limited in scope to justify definite conclusions, the following general comparisons with standard motion picture equipment and techniques appear to be ustified:

1. The equipment is not fully portable. This remark applies particularly to the video recorder unit.

2. The equipment is not completely reliable. While engineered and manufactured to high standards, failures are much more common than in the more familiar motion picture sound equipment. Constant maintenance is required.

3. A larger production crew is required. The minimum increase consists of one camera control unit operator for camera, a technical director and an operator for the video recorder.

4. Substantial saving in time and complete elimination of editorial and re-recording cost is possible.

5. Pictorial quality, while not up to motion picture standards, is acceptable for most types of subject matter encountered in training film production. The picture looks better than a purely mathematical analysis of resolution would indicate.

6. Sound quality, due to the elimination of several re-recording generations, is better than average for 16-mm prints.

In conclusion, the high initial cost of television equipment requires a large volume of production before reduction of editorial costs make this type of operation economically feasible. The large amount of time saved might make this technique desirable for some producers in spite of the economic penalty.

From the Navy's point of view, the production workload does not appear to warrant purchase of such equipment at this time. In time of full mobilization, when the workload greatly increases and production time must be greatly shortened, it is probable that serious consideration will be given to employing this technique.

Acknowledgment is hereby made to the personnel of General Precision Laboratory, whose enthusiastic cooperation made this experiment possible. The film made in the course of the experiment is now in use and is adequately fulfilling its purpose.

Techniques for the Production of Electronic Motion Pictures

By E. A. HUNGERFORD, JR.

This paper examines the techniques now current and estimates the possibilities of accomplishing the production of truly electronic motion pictures of sufficient technical quality to reproject into the television broadcast channels.

SEVERAL high-speed techniques for motion picture production have made their appearance in the last few years. The goal of these techniques is to produce motion pictures at a cost the television industry can afford to pay. All of these techniques are logical progressions toward the ultimate method of producing movies using high-resolution television cameras which feed to high-quality video recorders for picture and the usual film recorders for sound.

Television broadcasting has grown much more rapidly than was ever anticipated. With this growth has come a demand for visual programming which severely taxes the facilities and talent of the entertainment world.

In the beginning, television borrowed from all existing allied fields. From the theater came talent who could give a sustained performance since television is a real time medium. From radio came the know-how in electronics and the production techniques for handling special events and sports. From radio, too, came money by the millions of dollars. Even though radio knew that nurturing television would put its balance sheet in jeopardy for the years until television became profitable, radio plowed ahead with full confidence that the day of profits would eventually come. It is now nearly here. One great television network has recently reported black-ink operations; many individual stations have achieved this goal.

Television borrowed from motion pictures, too. A visit to the early television studios was a visit to Hollywood in miniature. The lights were identical; the camera dollies were the same; so were the microphone booms. Every applicable production trick was borrowed to get television under way.

Production Time Reduced

Soon some changes began to occur. Fixed lighting was replaced by systems which could be controlled during performances. New types of dollies ap-

Presented on May 3, 1951, at the Society's Convention at New York, by E. A. Hungerford, Jr., General Precision Laboratory, Inc., Pleasantville, N.Y.

peared. New techniques developed. Always the goal was the same—to speed up production of visual material. In the last ten years much progress has been made in fast techniques for television production. For example, complete one-hour dramatic programs are produced in three to five weeks. Actual camera rehearsal time is often only eight to twelve hours. Yet the final production is much like a feature motion picture. Since most such programs are produced live, the actors give sustained performances, which further heightens the effect.

Television has now grown up and is ready to pay its debt to motion pictures.

Some of these same high-speed techniques are adaptable to the moving picture industry and will bring the costs of production down to a point where television can pay for the costs involved.

At this point it is appropriate to ask the question, "Does Hollywood really want to produce films for television?" The answer must come back in the affirmative for several reasons. First of all, the quantity of film required by television so far exceeds the imagination that from a quantity viewpoint alone the market is attractive. And if production can be artistic, too, it will represent a real challenge to the ingenuity of Hollywood. But there is another very big reason. This has its roots in the theater, the outlet for Hollywood products. The theater today is undergoing a major adjustment. It is faced with direct competition for the first time: a small but lively lighted bottle in millions of television homes—essentially moving pictures, even though on pocket-sized screens. Many theaters realize that the best way to fight fire is with fire and the move to theater television is on. What will this mean?

Already one or two theaters are piping a television newsreel to their big screens. Television can and does do news better than the newsreels can hope to do. Soon there will be special events for theater television.* Some circuits even plan their own studios to generate variety shows for their big screen theater television. This will inevitably take away playing time from feature pictures. It now seems probable that the second feature may ultimately be replaced by theater television productions. To Hollywood this must mean less feature picture production for the theater, more overhead to spread over fewer pictures. This is hardly the way for an industry to advance in these competitive times. So Hollywood will have to look to a new market to make more efficient use of its splendid facilities for picture production. In seeking this new market no matter where it turns, Hollywood will encounter television and its voracious appetite for visual material.

To serve this market Hollywood will have to devise lower cost production methods because the day is still distant when television can spend $1,000,000 and up to run a feature picture. So, now motion pictures can borrow back from television some of the tricks which television has of necessity had to develop to cut its own production costs. Already the gap is being closed between high- and low-cost production. Let us examine the progress to date and see where it leads.

The Search for Economy

About a year ago an experiment was begun in Hollywood in connection with the Groucho Marx television show. The performance was strictly a radio show played in a typical radio studio. On the stage was a plain backdrop in front of which Mr. Marx seated himself on a stool. Here he met and interviewed his guests. From the center stage angle and shooting from the audience was a 35-mm

*Since the writing of this paper, several showings of sporting events have been made over exclusive theater television networks. The success of these demonstrations has proved beyond doubt the practicability and appeal of this medium.

motion picture camera. From stage left and from stage right were two other 35-mm cameras—all three grinding away continuously. At each location was another camera loaded with film and ready to take over when the active cameras ran low on film. In this way continuity could be maintained indefinitely. The cameras at stage left and stage right concentrated on close-ups while the camera at center stage angle provided the cover shot. By skillful editing, a motion picture was produced which had high impact and which constituted a very fine television show of high technical quality.

Here was a motion picture made in real time and, though a lot of film was probably destined for the cutting room floor, this waste was not large in terms of the value of the show as a whole. Yet the search for greater economy continued.

Next a system was devised where the director of the production would turn on a selection of motion picture cameras on cue to photograph a rehearsed script so that only the desired shot was being recorded on film. This saved film and also simplified editing and reduced the time from shooting to a finished print.

Evolution of Electronic Techniques

This latter system is much closer to the television technique in that some editing is attempted in the shooting of the scene. Then came the Vidicam system.

This next step was inevitable—the transition to the use of electronic viewfinders on film cameras. This system, now in actual use by the Vidicam Pictures Corp. of New York, operates as follows: To permit the producer to see what he is shooting a small television camera is mounted alongside the motion picture camera. The television camera is mechanically adjusted to see the same scene as that being viewed by the motion picture camera. The production is handled just as a television program would be handled. The director selects his shots on television monitors and instructs his cameramen in proper movement. When he selects his television shot he simultaneously starts the associated motion picture camera. Suitable bloops are applied to the sound track to assist in editing. This is really television production monitored by celluloid recording. Editing is practically accomplished as the production unfolds. Little or no film is wasted. Here is efficient production. The sustained performance is encouraged to the greatest extent possible. It is now practicable, with such a system, to turn out two 15-minute dramatic bits completely in a day's time including all rehearsals.

It is but a short step from Vidicam to the fully electronic technique. The motion picture camera is merely moved back into the laboratory next to the sound recorder and the picture is recorded in like manner by photographing a high-quality television image of suitable brilliance. Here is the way to capture all the time saving elements of television production for only television equipment is used. Picture recording is handled exactly as sound recording has been handled for twenty years. Television is paying back its debt to motion pictures. In return for the techniques borrowed in its earliest beginnings, television returns a smooth high-speed production technique well suited to turning out films for television use on a mass basis.

The Need for Higher Quality

The above technique viewed another way is really a kinescope recording and as such does not enjoy an enviable reputation for quality as yet. But the results are improving fast and over the past two years new equipment has come on the market which equals the best that can be done with 16-mm film even when photographed directly. And these results can be still much better. Present-day television camera equipment is designed to feed television transmitters for home television. The limitations in the trans-

mitters and in the home receivers are dictated by the standards set for home broadcasting. It is possible, however, to build far better television cameras and associated equipment, including video recorders, which will produce results closely approximating those obtained by direct photography on 35-mm film.

Within a year such equipment will be available to the motion picture producer. This will enable him to use all the television techniques to produce electronic motion pictures whose quality, when transmitted over the commercial broadcast channels, will exceed that presently available from the best live talent productions.

Design personnel at this Laboratory are about to introduce a higher resolution television system. The need for this is well recognized in the field of theater television. Present broadcast standards of four megacycles are insufficient to meet the requirements of large-screen projection in the theater. The new cameras and associated equipment will produce pictures which are nearly twice as good as present-day broadcast images. When such images are recorded on equally good video recording equipment, the resulting motion picture film will approximate the quality of 35-mm original photography.

How then, will this transition to electronic motion picture production be made? It will probably occur in several different ways. The first successes will come to those who are already experimenting with high-speed motion picture production methods, like Vidicam. They will adapt quickly and easily to the new technique. They are practically there already. By the addition of a video recorder, a continuous rapid processor and a projector it is now possible to expand the Vidicam system to produce an "answer" sound print which the sponsor can have immediately for approval and review. Such a system for audition work and rehearsal "rushes" can be the most economical short-cut to fast production. If high-quality television cameras are used with Vidicam systems, the day will soon come when the electronic recording will suffice for most purposes—for telecasting, review and nontheatrical distribution.

The armed services are also a factor in this area. Always alert to any method for producing training films in less time, the Navy Photographic Center recently made a test film using television equipment supplied by this Laboratory. This experiment is the subject of the paper by Lt. Comdr. J. S. Leffen in this issue of the JOURNAL. It is only necessary to state here that the experiment was successful: a 20-minute training film was produced in fourteen hours of camera time. Experience would cut that figure appreciably.

At the Navy Special Devices Center, experimentation with the effectiveness of television for education has been going on since 1946. To better study the results of experimental programs kinescope recording facilities were installed at the Center. As a part of the competitive testing of live classroom instruction versus live television training, a test of the kinescope recordings was also conducted. This latter phase proved that the recordings had nearly the same impact as the live television performance. It soon became apparent that the kinescope recordings were a very valuable end product in themselves. They were used extensively in training. This work led to the experiment at the Naval Photographic Center, the results of which you have seen.

Hollywood producers in the larger companies will probably arrive at this electronic motion picture technique by another route. When the motion picture theaters begin to exploit theater television extensively, they will look to Hollywood to supply the material to transmit to the theater, just as they have always looked to Hollywood for screen fare. To meet these requirements, the major studios will undoubtedly install

television equipment and begin to gain the necessary experience with the technical phases of the television medium so that they can bring to bear the full force of their artistic achievement. In meeting this need, there will be many times when it will be more efficient and expeditious to produce these theater television epics during the day rather than at the particular time required by the theater schedule. So these programs will be recorded by high-quality video recording apparatus and played into the circuit at the appropriate screen time. At this point, or before, Hollywood will be in the thick of producing electronic movies and will have become so skilled in these techniques that networks will be vying with one another to buy such a product. The age of the electronic motion picture will have been born. The motion picture and the television industries will have moved many steps closer together. This is, of course, essential for the continued growth of each.

As the television medium assumes its full national stature and becomes a broadcasting industry of greater scope by far than radio, it will offer a new and tremendous market to the motion picture industry for a suitable product, a market which can be efficiently and successfully met by the adoption of high-speed motion picture techniques and, finally, fully electronic motion picture production techniques.

Practical Operation of a Small Motion Picture Studio

By MORTON H. READ and EUGENE N. BUNTING

The problems and methods of handling television film commercial and short productions economically and in a limited space are outlined.

THE TERM "small" as applied to motion picture production studios is a relative one, and its proper use depends entirely on comparison. I have no idea how the operation of our business compares to the film business in general with the exception of specific cases which are familiar to everyone in the industry. Thus, we are very small as compared to Hollywood theatrical operations, small when compared to the larger and better known of the so-called industrial producers, but perhaps the term "medium" might be applied to our operations when compared to the many organizations which operate on a much smaller scale than do we. So that the reader of this paper may find his own estimate of our size, the following list may be helpful.

1. A sound stage of 3000 sq ft,
2. Camera and lighting facilities including a portable 15-kw field generator,
3. Sound Department, including a 16-mm film recorder, $\frac{1}{4}$-in. and $17\frac{1}{2}$-mm magnetic recorders and phonographs,
4. Printing facilities for black-and-white and color duplicates.
5. 16-Mm black-and-white machine processing,
6. Cutting, editing and screening facilities,
7. Animation facilities, and
8. A production, creative and sales staff, totaling 15 persons.

There is more than one reason why small motion picture studios exist. The reason can be from the standpoint of: (1) economics, (2) efficiency, or (3) business conditions peculiar to a given geographical area. All of these reasons have had an effect upon our growth, the last one most of all.

New England is different from some sections of the country when it comes to spending money. Our clients want quality, but they don't want to pay what they call "fabulous prices" for motion picture production; and, in fact, if New England clients could not buy motion pictures within certain price ranges, they would not buy at all. But in spite of our limitations and conditions imposed upon us, we must produce motion pictures which compare favorably with those produced by almost anyone else in the business.

The increasing number of television productions has made it necessary to add speed without sacrificing quality, a requirement which we feel has added to, rather than subtracted from, efficiency. And so we have developed certain techniques to accomplish what must be done, some new versions of old methods and some new.

Perhaps the most important factor in the successful operation of a small studio is the selection of a staff. This selection may make or break the business because the cost of overhead is the

Presented on April 30, 1951, at the Society's Convention in New York, by Morton H. Read, President, Bay State Film Productions, 458 Bridge St., Springfield, Mass.

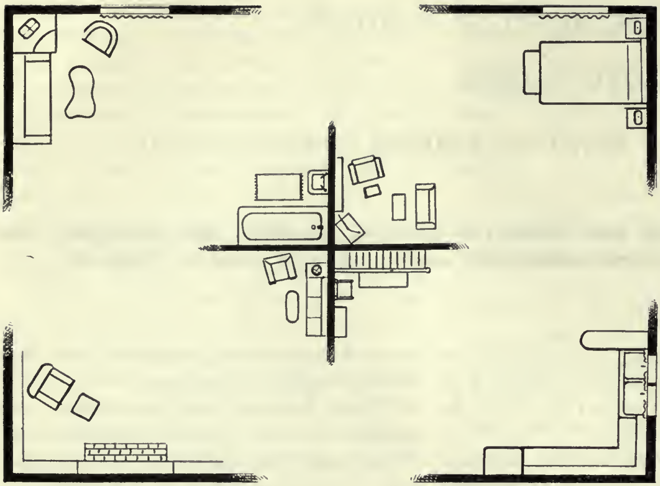


Fig. 1. Studio Arrangement.

greatest single enemy. Wherever possible, it is desirable to select or train men who are capable in more than one phase of production.

There is almost no place for single-job specialists here. To be sure, there will have to be some single-job men such as those in the laboratory who are closely confined to their work; but our three cameramen must also do lighting, animation, editing, matching, cutting and splicing. Our sound engineer must also be the recordist, do musical scoring and maintain the equipment. For that matter, anyone who elects to spend his business life in a small motion picture studio, must plan to do many different operations. Some might think that such a set-up makes for inefficiency and chaos, but there is advantage in close cooperation and integration, which make possible a follow-through well nigh impossible in any other type of organization.

Set design in a small studio can be something of a problem, especially if it is necessary to have several sets ready at the same time. When budgets are low and space is limited, casts cannot be kept on subsistence while sets are changed and the studio is rearranged. This is especially true when a series of television commercials involves (as they often do) a kitchen, dining room, living room, hallway with front door, etc. If the studio can be completely set up in advance with all top lighting in place, it's possible to do a vast amount of work in a minimum of time.

Studio Arrangement

Figure 1 illustrates a type of studio arrangement which is probably not original, but which we have not seen elsewhere. It provides four fairly sizable, two-wall sets and four smaller two-wall sets. The four corners of the studio are used for kitchen, bedroom, dining room, living room, etc., while the unit in the center will handle a small bathroom, a hallway, doorway room corner, etc. This center unit is rather interesting since it is designed to fold flat and can be wheeled out of the way on a small dolly. This arrangement would not work too well for production demanding three-wall sets, but it works to great advantage in television and allows complete use of the entire sound stage. In planning a shooting schedule, it will be found more efficient to complete scenes in the center

section first, then roll that section out of the way for work on the corner sets.

Many small producers have made a practice of doing television work on location and, in isolated cases, such a procedure may work to advantage. In our experience, however, it is always preferable to work in the studio where every phase of production is under control.

Production techniques in small studios are, of course, based on standard practices worked out by the experts. Almost everyone who does not possess facilities for manufacture or development, buys his entire equipment packaged and ready to use. But it would require a lot more money than the usual small producer has, to own everything he will require to accomplish the great variety of demands which will be made upon him. It is then that his ingenuity must be put to work if he is going to compete. It is then that gimmicks and gadgets make their appearance and equipment begins to do and do well, jobs that were never intended for it. Many Bell & Howell projectors have been modified with synchronous motor drive. Old projector amplifiers are now doing duty as parts of sound readers and many fine old cameras are working again in various versions of an optical printer. The adaptations are not haywire. They are doing a good practical job. The small studio is what it now is because of ingenuity and hard work.

At this point in the Convention presentation there was shown a short portion of a color print, *The Will to Be Remembered*, produced for the Barre Granite Association, Barre, Vt.

Improvisation

There was more than one reason why the print projected was chosen for the meeting. Besides the subject matter, it is a typical example of production in a small motion picture studio. By that, I mean the use of equipment never intended to do the work for which it was made. A small production unit advances slowly in its acquisition of fine cine equipment, but it still must turn out the work.

The print was made on a Depue, double-head, continuous printer operating at 76 ft/min. A resistance light control board was used for varying light intensity and all fades and dissolves were made simply with A&B rolls and cutting the current from the printer lamp. Obviously, with a double-head machine, the sound track was printed in contact, but should it seem that the whole list of taboos for color printing has now been completed, there is one still to come. The re-recording of the voice track was made from a standard, synchronously driven, Bell & Howell projector. No change was made in the optical system although resistance and matching systems were introduced in the projector amplifier output.

This system of re-recording is one we have long since abandoned but, though unorthodox, it can be made to work well. For some time now, we have been using a system of magnetic tape transfer in re-recording. Perhaps this method of tape transfer might be interesting to those who are not blessed with three-phase interlock and all that goes with it. We were using magnetic transfer long before there was any publicity about it and the method is so simple that anyone can use it. Our particular set-up involves a standard Magnecorder, $\frac{1}{4}$-in. tape recorder and a Kinevox $17\frac{1}{2}$-mm magnetic film recorder and phonograph. Since manipulation of the starting switch on the Magnecorder will allow the drive mechanism to operate without transporting tape, it is possible to start and stop the transport at any given time. Our system is to measure the final cut work print of a film and provide the recordist with a copy of the script which has each section of the narration marked off in linear measurement. By refer-

ring to a synchronous footage counter and starting and stopping the Magnecorder as indicated, it is a simple matter to transfer wild narration track to the synchronous magnetic film in just ten minutes per reel. There is no cutting of tape or film track, no bloops to worry about, no worry about the handling of the medium which is to be recorded. If the recordist makes an error, he simply notes it, finishes the reel and then goes back to erase the area where the mistake was made so that he can fill in that particular narration.

There is no controversy between the theoretical and the practical in the small motion picture studio. I feel sure that everyone in the business would be perfectly equipped if he had the choice. But any business must grow and in growing must turn out quality or fall by the wayside; and if survival is the *only* reason, a way will be found to make quality a reality. The small studio has one very great advantage over its larger counterparts. That advantage is a close-knit, compact organization with little or no distance between the man who develops an idea and the man who executes it. We are blessed with a group every one of whom is vitally interested in turning out the best possible job. Since a great many small studios survive and continue to grow, it seems safe to assume that our situation is not peculiar to us.

Most small producers rely on practical methods of control throughout the whole operation. It sounds trite to say that such control is merely the judgment of what looks and sounds good, but in effect that is so. In color work especially, the highly specialized machinery for color analysis is denied the small studio because of cost alone, and some other means must be found to bring about consistent results. A good deal of interest has been expressed in our particular color control methods and although I feel quite sure that they are not greatly different or outstanding, they are outlined below. The methods may prove interesting simply as a means of comparison to those in general use. The basic rules are as follows:

1. Employ as few color correction filters in the printer pack as possible.
2. Careful voltage control of the printer exposure lamps.
3. Standardized test for each stock emulsion number.
4. Standard color patches on each print.

Color Control

The gauge or color patch consists of twelve color patches representing different mixtures of the three basic colors, magenta, cyan and yellow. Because corrections are to be made visually and not by instrument, each patch is a full frame in size. In our opinion, it is important that these patches are not pure basic colors, since if they were, small contamination by an odd color would not be easily detected. These color patches are made up of 50–50 mixtures of cyan–yellow, yellow–magenta, magenta–cyan and certain deviations from the 50–50 mixtures. We find that these patches reveal errors that may be quite small. [Slide projected here.] The patches at the top of the slide are the original ones shot in the camera; those in the center are a set from several hundred which were duplicated in the printer and which are attached to each print; and those at the bottom were cut from a print.

When a stock test or print returns from the laboratory, the color patches are visually compared over a constant light source with the gauge from which it was printed. It would be very unusual to find all patches out of balance, rather than only those most affected by the color which is in the wrong proportion. Thus too much yellow in the filter pack will not greatly affect those patches which are made up of a high percentage of yellow nor will too much magenta greatly affect the magenta patch.

But an excess of magenta, will show up in the green patch causing it to turn brownish by comparison with the original from which it was printed. Similarly, an excess of yellow would be detected in the violet patch by causing it to appear reddish by comparison to the original; and an excess of cyan would be apparent in the yellow patch by a green cast.

It is surprising how this comparison test will show up even minute discrepancies in the color balance. By holding the proper filter of the right density over either the original patch or the printed one, as the case may be, and examining the result over a constant light source, the two gauges can be made to match. It is then easy to judge as to what change in the filter pack should be made. If the original was made to match the print, then a subtraction must be made from the pack, but if the print was made to match the original, the pack will need a filter added to it. Of course, a great deal will depend upon the technician who is handling the matching problem and considerable experience is necessary before consistent results are possible. Even as a cameraman allows his judgment to influence his exposures regardless of meter readings, so must the lab man make his decisions in the light of his past experiences. The system works very well in our laboratory and should certainly operate elsewhere with the same good reliability.

Production for Television

Even the smallest studio outside of metropolitan areas will find that sooner or later it must have some type of machine processing for black-and-white films if it is going to make television deadlines. There is no adequate processing service in New England and we found much of our profit being disbursed in messenger fees, plane fares and 'phone calls—not to mention the wear and tear on the nervous system. A simple, but very efficient processing machine for negative and positive processing is made by the Bridgmatic Company and we have found ours very satisfactory for the volume of work we have to do. Later models of this machine have incorporated a number of advantages including refrigeration units for cooling, but ours is the simplest model employing four 10-gal tanks, a dry box and a trouble-free film transport system. The machine has its limitations, of course, but with proper handling it does a fine job. For cooling we installed a window air conditioner controlled by a room thermostat and our processing quarters are small enough to keep everything, including solutions, at the proper temperature. For heating, pieces of Calrod strip were attached to the tanks which are also controlled by thermostat. We did find it desirable to increase the strength of the average hypo solutions about one and a half times to obtain complete clearing. When processing certain emulsions such as Eastman Kodak negative 5230 and 5240, even this intensified hypo solution fails to do a good job of clearing if more than 4000 ft of film has been processed in it; in which case, hypo is also used in the short stop tank.

Our particular machine uses steel, rubber-coated tanks and we have found it desirable to recoat them every six months with Du Pont Fairprene cement.

The problems of the small motion picture studio and laboratory might well seem unsolvable to those who have gone many years beyond that stage of development, but I am sure that men and women who have been through the early stages, no matter where they find themselves today, will sympathize and appreciate what is being done in small quarters all over the country. Only those who have been set down in the midst of all the highly specialized machinery, the glory of the motion picture business today, may find us hard to understand. However, the small producer is here, I am sure, to stay.

Direct-Reading Light Flux Meter

By G. GAGLIARDI and A. T. WILLIAMS

The meter described in this article will measure the total lumens output of the projector and, by means of aperture plates, the light distribution over the screen. These measurements are taken by holding the meter directly in front of the projection lens. The "off" projector can be checked and adjusted just prior to use.

During the past ten or fifteen years considerable work has been done by the Society to obtain satisfactory meters which would measure screen illumination and brightness. Theoretically, the problem is not difficult but in practice the resulting meters are either too difficult to use or too expensive to be practical. This is particularly true in the case of a satisfactory brightness meter. Several satisfactory illumination meters have been described and used. In the March 1948 Journal the Screen Brightness Committee recommended a procedure of measuring the illumination by means of a visually corrected foot-candle meter. This procedure necessitated taking illumination measurements at five points on the screen and from these five foot-candle values a weighted average is calculated which, when multiplied by the effective screen area, in square feet, equals the lumens on the screen. This procedure often entails the use of extension poles in connection with the photocell targets or the use of ladders and precarious climbing on the part of the observer in order to reach the center and top of the screens. Some of the screens in drive-in theaters are so large that balloons have been used to lift the photocell to the high spots on the screen. At best it is a long procedure and one that can be done only during off hours. In drive-in theaters it can be done only after the last show because of the high ambient light at any other time.

The new instrument, described later, was developed to measure the total light output of any projection system, and the side and center illumination, without leaving the projection room. All of these measurements can be obtained readily and quickly during show time and without causing any interruptions. The measurements are taken under actual operating conditions and include working parts, filters, lenses and shutters.

Light Flux Meter

The Light Flux Meter shown in Fig. 1 consists of three basic parts: the integrating chamber which contains the photocell, the meter mounted in a case containing the selector switch and

Presented on May 2, 1951, at the Society's Convention at New York, by G. Gagliardi, Warner Brothers Theaters, Newark, N.J., and A. T. Williams, Weston Electrical Instrument Corp., Newark 5, N.J.

Fig. 1. Light Flux Meter.

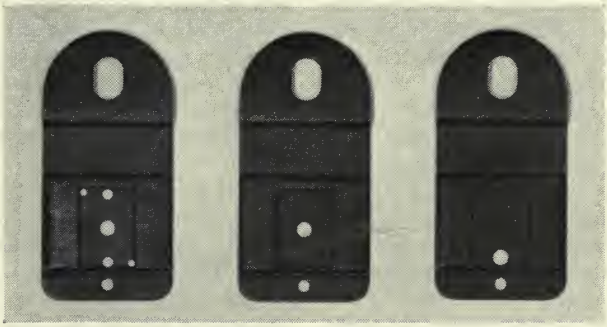


Fig. 2. Aperture plates.

attentuating resistors, and a series of aperture plates to measure both total lumens and light distribution on the screen. All of these values can be measured in the projection room.

The integrating chamber should theoretically be a large sphere with a small aperture but this is impractical for this application because such a sphere would be unwieldy and would not fit in front of the projectors in many booths. The integrating chamber used in this design actually consists of a hemisphere having an inside diameter of approximately 4 in. and a short cylindrical tube which joins the hemisphere with the two diffusing glass windows. The inside surface of the hemisphere and tube is coated with a lacquer having a white matte finish which produces excellent light diffusion. The location of the photocell and proper baffling to prevent direct light from striking it were carefully worked out with the result that the errors due to using various sizes of projection lenses are quite negligible.

The photocell is a dry disc barrier-layer cell and is equipped with a filter which corrects it to the standard lumi-

nosity curve as specified by the International Committee on Illumination.

The meter is a permanent magnet, movable coil type of microammeter having two scales calibrated 0.0 to 15.0 and 0.0 to 7.5 kilolumens. A selector switch allows the choice of either range.

The aperture plates, shown in Fig. 2, serve two purposes. The aperture plate containing five circular perforations is used when the total lumens are to be measured. These holes are located in such positions on the plate as to simulate the five screen reading method recommended by the Screen Brightness Committee. The total area of the five perforations equals one-tenth of the area of a standard film aperture. The individual area of each perforation was graded in an attempt to give them the same weighting effect as the committee recommended. The center hole was made twice the area of one side hole and four times the area of one corner hole. In addition to the weighting effect, the aperture plate, because of its 10% transmission, reduces the temperature to safe values on the lens and on the integrating chamber and photocell.

A single-hole plate is used to measure the relative light at the center of the screen and similar single-hole plates with the holes at the corners or edges can be used to measure the relative light values at other corresponding areas of the screen. These readings can be used to indicate relative illumination values, or the foot-candles can be readily computed by means of a simple formula. For example, if we make the hole diameter on each single-hole plate such that the area of the hole is 5% of the total area of the film aperture then the light intensity on any screen can be calculated. The light intensity, or foot-candles (I) will be a function of the screen size but since the ratio of screen height and screen width is a constant the screen areas will be proportional to the screen width squared (W^2). By measuring the lumens output (L) with the single-hole aperture plate in the film gate and the effective screen width (W) the light intensity can be calculated by the following formula

$$\text{Foot-candles} = \frac{2.74L}{W^2}$$

In the above formula a 5% area plate was assumed. If it is desired to round out the formula then instead of using a 0.1775-in. hole, which is the 5% area size, the hole diameter can be decreased to 0.1697 in. which will have 4.58% of the total area of the film aperture. In this case the formula will be as follows:

$$\text{Foot-candles} = \frac{3L}{W^2}$$

Fifteen theaters were surveyed using this Light Flux Meter. Values were also obtained by using a foot-candle meter and calculations as described in the Report of the Screen Brightness Committee in the March 1948 JOURNAL. Based on tests both in the laboratory and in the field with lenses of different focal lengths and different speeds, it was found that the maximum difference between the values obtained with the Light Flux Meter and the procedure specified by the Screen Brightness Committee was 8% but that the average was better than ±5%.

The advantages of the Light Flux Meter may be summarized as follows:

1. All measurements can be made in the projection room.

2. Measurements can be made during the performance on the "off" machine without interrupting the show.

3. Adjustments can be made simultaneously with the measurements.

4. Comparative measurements can be made quickly when any item of the equipment is changed.

5. Check-up for peak performance may be made as often as desired without any extra expense or inconvenience.

6. No external or internal source of power is required to operate the meter.

Discussion

K. Pestrecov: Is the instrument available commercially?

A. T. Williams: Unfortunately, it is not available. Our company is so tied up with war work that I doubt we could make one up. However, it is possible that some smaller company may take over the development and we are willing to turn over the design and the data that we have to some company that may do that. Mr. Gagliardi is working on that now. We would be glad to lend the instrument out for a reasonable time to anyone who wishes to do experimental work with it. We merely made this up in answer to a demand, but unfortunately, we are not in a position to manufacture it.

W. W. Lozier: The Screen Brightness Committee would be glad to accept that offer and use the meter. Is there any way of taking into account the effect of the screen? That is the one link we lack after we have the incident illumination.

Mr. Williams: No, unfortunately this does not consider the reflectivity or the polar characteristics of the screen surface. We merely measure the incident illumination.

R. H. Heacock: Is it put out in front of the projection lens?

Mr. Williams: That is right. It is used right in the booth, and is put over the front of the projection lens.

H. J. Benham: It would seem to me that the image would have to fill rather exactly the space that you had set aside to correspond to the projector aperture. Does that mean then that you move this device back and forth until you get it the exact size that fills the space you indicated on your little mask?

Mr. Williams: No, the instrument is put directly in front of the lens. The mask is placed in the projector aperture itself, and therefore limits and defines the light passed on to the lens and the meter. Use of the integrating sphere enables the instrument to integrate correctly the intensities of the light beam irrespective of whether the projection lens has a focal length of $2\frac{1}{2}$ in., 3 in. or 5 in., for example.

Dr. Lozier: It will integrate a small cross-section beam as well as a large one within the diameter of the pickup element.

L. Martin: I imagine a useful application of this meter might be the balancing of two or more projectors so that uniform brightness is obtained when you change over from one to the other. Was it Mr. Gagliardi's intention to provide a meter that would be in continuous use during the show to keep the projectors properly balanced? Did your tests indicate why there are discrepancies in light output between projectors?

G. Gagliardi: We have actually used it during the show in many instances. It is possible to take a series of readings from any projector at the end of a reel, after a change-over has been made. Only a few minutes are required for the readings, and possible adjustments, so that all projectors can be balanced without causing any interruptions.

This instrument could be used continuously or at periodic intervals in order to check the balance between projectors as well as their maximum output. Tests in the field indicated that most of our machines were fairly well balanced. Discrepancies between projectors were usually traced to changes in carbon position or in relative position between lamphouse reflector and projector aperture plate.

In the shop or in the factory, where we made a lot of other tests, we were able to detect small differences in readings, depending upon carbon position, reflector position, changes in lenses and reflectors, and general equipment alignment. In other words, it was possible to tune the system to maximum output without looking at the screen, merely by looking at the meter.

The choice of scale is something that can be determined later. We chose 7500 and 15,000 lm because those values seem to be the mean and maximum output of the present projection systems with the shutters running. That is another thing you can determine: whether the shutter is set at 50% transmission, or more or less. All of these things can be measured at your own convenience in the projection room if you wish to do so, or they can be measured anywhere else for that matter.

I know that in actual operation the readings of light intensity taken at the screen have varied widely. In order to get a decent average it may be necessary to repeat a set of five measurements several

times and average them, because you cannot depend on one reading alone. The new meter integrates and totalizes all the readings at once, so that the changes in the total value of light flux may be followed very readily. It is possible to follow the variation in light flux as the carbons are moved by the arc feed mechanism.

Mr. Martin: Mr. Gagliardi's answer would indicate this is more a laboratory instrument for the initial adjustment of the projector than an instrument to be used constantly in the projection room in order to keep the projectors in balance during the performance.

Mr. Gagliardi: I don't think that in most of our theaters you need to check the projectors between each 20-min operation. However, you can use it as often as you please.

Mr. Martin: I wasn't proposing that you do. I just wondered whether your measurements indicated any need for it or not, and I think you've answered my question.

L. W. Davee: I have followed the work that Mr. Gagliardi has been doing for several years and I think that this instrument is the culmination of one of the finest pieces of work which has been presented before this Society or in this industry for a number of years. I have been a very enthusiastic supporter of this development. This is not a piece of laboratory equipment. I believe it is a piece of equipment to be used by every equipment salesman and every dealer and every serviceman. I have nothing to do with selling these devices; I have no connection with them. I believe that the use of this meter, in other words the widespread use of this meter, will take some of the fallacies out of some of the sales stories a lot of salesmen in this country use in selling projection equipment, and I, for one, would like to see this meter adopted very, very widely. It would serve as a basis for comparison, it would standardize our industry, it would make our industry the type of industry I would like to see. As projector manufacturers, we would welcome such a piece of equipment on the market today so that we could come down to a basis for comparison of relative values of the equipment that is now offered to the theaters.

New Processing-Machine Film Spool for Use With Either 35-Mm or 16-Mm Film

By F. L. BRAY

It was decided that a new film processing machine at Du Art Film Laboratories, Inc., should be capable of handling either 16-mm or 35-mm film. After a number of experiments to find the best sprocket and spool combination, a radically new type of spool distinguished by a tapered profile was chosen. The advantages of this design, as applied to sprocket-drive and friction-drive machines, are enumerated.

WHEN IT WAS decided that the new 35-mm developing machine being built at Du Art Film Laboratories should, if at all possible, be capable of processing 16-mm film interchangeably with the standard width, the general lines and type of design had already been established.

This machine was to have some 58 spool banks of a type that is quite orthodox for a sprocket-drive machine. The top shaft is driven, and with it the film sprocket. The film spools on the top shaft are not secured to the shaft, but do have a tendency to rotate at the same speed as the shaft. The lower spools are all as free as possible on their shaft, and the carriage on which they are mounted is free to move straight up and down, but in no other manner. The weight of this carriage is supported entirely by the loops of film, which are thus kept in suitable tension regardless of the swelling and shrinking of the film as it progresses through the stages of processing and drying.

Presented on April 30, 1951, at the Society's Convention at New York, by F. L. Bray, Du Art Film Laboratories, Inc., 245 West 55 St., New York 19, N. Y.

Tentative Approaches

The first thought, probably, that would occur to anybody with this problem (of designing a dual-purpose processing machine) would be something like Fig. 1A. It would be easy enough to recess the 16-mm portion of the sprocket deeply enough so that 35-mm film would bridge the 16-mm teeth with plenty of clearance. Of course the two kinds of film will travel at different linear speeds, but since all spools are idlers they will run at whatever rotational speed is required of them.

The technique of changing over from 35-mm to 16-mm involves the use of an unperforated strip of machine leader tapered in width from 35-mm to 16-mm over a length of several feet. This is run through the machine slowly to make sure that the change-over is successfully accomplished. From the first we were willing to accept this step as practically unavoidable.

Now, referring to the spool-sprocket combination of Fig. 1A, we should note

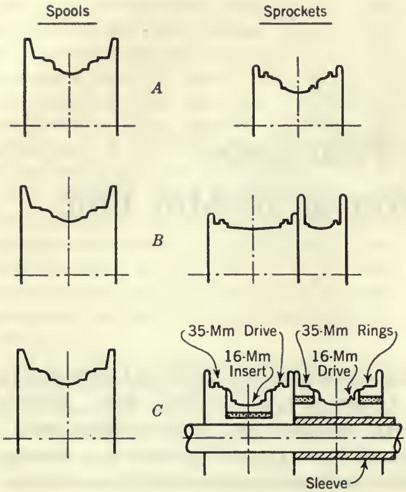


Figure 1.

that one serious difficulty threatened. In making a change-over, say from 35-mm to 16-mm, would not the film break immediately, due to the failure of the 16-mm sprocket to feed film as fast as it is demanded by the 35-mm sprocket ahead? No; actually the elevator would rise until the change-over is completed for that particular film bank. Moreover, a little analysis shows that the elevator rise would be exactly proportional to the reduction in linear film speed, with the result that the processing time remains unchanged. Of course, had this arrangement been adopted the productive capacity of the machine for 16-mm film would have been some 25% less, in feet per minute, than for the 35-mm size, and this might or might not have been regarded as a serious matter.

The elimination of this elevator rise (or drop on going back to 35-mm film) might have been accomplished by using two sprockets having as nearly as possible the same pitch diameter, as shown in Fig. 1B. This would have required manually lifting the film from one sprocket to the other as the tapered change-over strip reached each successive pair. This operation would entail no great hardship, but would still take quite a long time to accomplish when, as in this particular case, the machine was to carry some 7000 ft of film.

It is not easy, nor would it be worth while, to recall all the proposals that were put forward and subsequently rejected. One of the more fanciful is shown in Fig. 1C. Here the idea was to have a pair of sprockets at the middle of each top spool shaft. One, the 35-mm driver, would be secured to the shaft, and contain a free-turning 16-mm insert without teeth. The other sprocket would be the 16-mm driver and would be fastened to a sleeve. This sprocket would in turn have had a pair of free-turning 35-mm rings. The sleeve was to be rotated slightly faster than the shaft, by means of a small speed-change gearbox at the end of each shaft, in order that both sizes of film should travel at the same linear speed. By this complex device it was hoped that all the time lost in making a change-over might be saved.

An Old Problem

During the foregoing period of concentration on sprocket design it was assumed that the spool would have to look about like those shown in Fig. 1, which are all the same. Now an ideal spool for 16-mm sound film seems never to have been made; so at about this point we began considering what kind of a compromise might be least objectionable for the 16-mm insert portion of our new combined spool. It is well-known that even very slight abrasions of the film base in the sound-track area can add noticeably to the ground-noise level of a 16-mm sound track. Therefore what was sought in the 16-mm profile of this new spool was a minimum of support on the sound-track side—that support to consist of soft rubber in contact with the very edge of the film base.

Accordingly the idea illustrated in Fig. 2A was tried—but it simply would not work. For when there was any con-

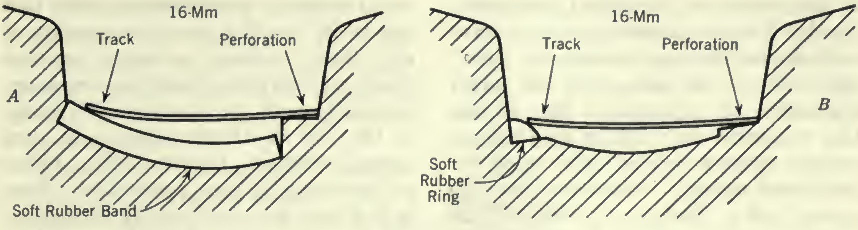


Figure 2.

tact at all on the sound-track side, the film would be drawn up the steep rubber slope until it was almost entirely supported on the sound track alone! This effect was conceived to be the same as that which causes a flat power transmission belt to seek the high side of a pulley—a principle that was subsequently turned to good account.

The next proposal for a 16-mm profile is shown in Fig. 2B. This soon had to be abandoned due to the difficulty of procuring the necessary quarter-round soft rubber in ring form.

Toward a Solution

About this time it became apparent that the whole idea of a composite spool with two different diameters might give a lot of trouble. In changing over from 16-mm to 35-mm, for example, there would inevitably be a series of 18 sharp yanks on the film, each requiring the elevator to rise approximately one-half inch as the film climbed upward and outward from the 16-mm channel to the 35-mm channel of each successive spool. In the opposite direction, changing back from 35-mm to 16-mm it is hard to predict what would happen, except that the operation would most certainly not be a smooth one.

We were familiar with the belief held by some that a level soft rubber surface over the entire width of the spool, such as shown in Fig. 3A, is quite harmless to the support side of motion picture films, since the unit pressure between film and spool is held at a low uniform level in this way. However, because of a desire to eliminate every possible hazard, it was decided to positively relieve the picture area at least, and the sound-track area also if a way could be found.

Equal Diameters, Yet Fully Relieved

Out of all the above considerations and experiences, there finally evolved an entirely new film spool, the profile of which is shown in Fig. 3B. The most characteristic feature of this spool is the taper, which of course is an application

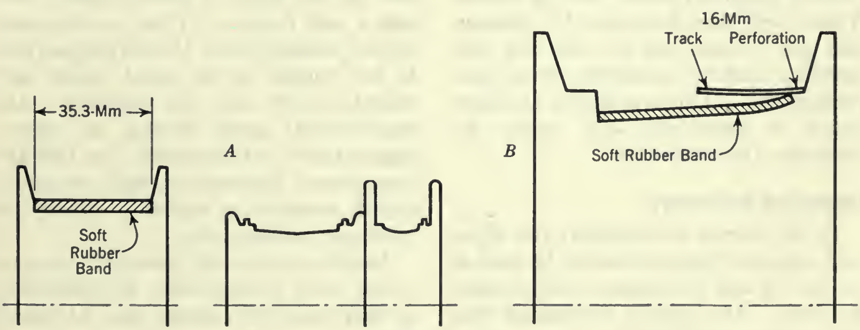


Figure 3.

of the experience described previously. 16-Mm film is threaded over this spool with the perforations toward the "high" side—that is, the side with the larger diameter. In operation, the 16-mm film maintains the shape of a cylindrical surface, making contact only along the perforated margin. Moreover, this film always has a tendency to "climb" toward the high side of the spool until stopped by the guide flange on that side, at which position it is shown in the illustration. 35-Mm film, of course, is carried by this spool in the usual position, resting upon the shoulders on both sides. The 35-mm sound track may be at either side, as it will be fully relieved either way.

While this spool has one apparent weak feature—which will be discussed below—it does meet every one of the objections heretofore encountered. It facilitates 16-mm production at full machine capacity. It fully relieves both the picture and the sound-track areas of 16-mm sound film. And, most important, it eliminates sudden slackness or yanks during change-overs.

The weak feature referred to is that the weight of the lower spool assemblies (elevators) is supported entirely by the perforation part of the 16-mm film strands. While tests have shown that eight or even four strands are ample to carry this load, it has been learned by trial that the presence of any torn perforations in 16-mm sound film must inevitably result in breaks. For an answer it has simply been determined in advance that any 16-mm film fed into this new machine must be completely free of torn perforations. This is a quality standard which is considered well within the capacity of the laboratory.

Operating Procedure

In the interest of simplicity two separate, adjacent sprockets are to be used as in Fig. 3A and the changes will be made by hand. The hope is entertained that the operators will learn to catch the tapered strip as it passes each sprocket pair and to lift the film from one sprocket to the other without reducing machine speed. Otherwise it will be necessary, of course, to fill the machine with leader at the end of 35-mm operations, then change over to 16-mm leader before commencing 16-mm processing. Even in this case, however, thanks to the constant spool diameter, it will be possible to run the machine at full speed during the actual change-over, only stopping momentarily at each sprocket, instead of having to run through 7000 ft at perhaps one-quarter speed.

Design Features

One or two of the details of this particular design may be of interest. The purpose of the increased slope at the high side of the spool is to provide a definite break between the supported portion of the film and the relieved portion. The purpose of the soft rubber band is to provide a low unit pressure supporting surface for any 16-mm film which may temporarily come into contact with the middle portion of the spool. In addition, this soft rubber, because of its relatively high coefficient of friction, assists materially in the steep climb required of the 16-mm film just before it reaches the shoulder on which it normally runs.

The actual amount of taper selected for the spool is four degrees. A simple test showed that this value permitted a misalignment between the supply roll and our test spool of approximately one and a half degrees. That is, with any greater misalignment, 16-mm film started in the middle of the spool would not reliably climb onto the shoulder. An experimental spool having an eight-degree taper was also made, but had an incongruous appearance, and was only slightly superior in regard to ability to overcome misalignment.

Another interesting discovery was that a little more misalignment is permissible at high linear film speeds than at lower ones.

Use With Friction-Drive Machines

This type of film spool may, it is hoped, be particularly applicable to friction-drive processing machines on which it is desired to run different film widths interchangeably.

In the usual friction drive machine, the type of film spool shown in Fig. 1 would be useless since, in changing over between the 35-mm and the 16-mm widths, there are no elevators to compensate for the difference in linear speed through the machine.

Provided that tensile stresses, particularly in the dry cabinet, are held within reasonable limits, there seems to be no reason why any friction-drive processing machine could not be readily designed or converted for satisfactory interchangeable service through the use of this new type of film spool.

Discussion

Gerald Graham: Are these spools on the market? Can you give us any information as to where they can be procured?

Mr. Bray: They can be purchased from either the Luzerne Rubber Co., of Trenton, N.J., or from Du Art Film Laboratories.

Nonphotographic Aspects of Motion Picture Production

By HERBERT MEYER

Motion picture technology is predominantly focused on photographic and other processes for recording action and sound. Few papers[1] have been contributed dealing with other technical activities pursued with commensurate skill, inventiveness and constantly expanding knowledge of materials and processes in Hollywood studios. Set construction and special effects present an amazing variety of problems little known or even suspected by outsiders as concerning motion picture production. This paper attempts a description of materials and techniques applying to set construction and special effects. Emphasis is placed on pointing out present technology, desirable improvements and possible developing trends.

Technically, the motion picture industry is recognized and typed by its predominant and obvious activities in the use of photography as a means of recording and reproducing action and sound. For this reason, other technological aspects which play a large and important part in the process of making a motion picture, are little known or recognized outside the studio.

This paper attempts to point out the many processes and materials which the average motion picture studio employs in activities that are generally grouped within the broad functions of set construction. Considering that the studio, to furnish proper settings for story background, must in the majority of cases construct and fabricate some or all of the sets instead of using existing locales, it becomes immediately apparent that the need for materials and fabricating methods in set construction is virtually unlimited and ever changing.

The Motion Picture Research Council,[2] in recognition of this fact, has spent considerable time and effort in contacting literally hundreds of chemical and allied-material manufacturers and fabricators to obtain guidance and collaboration in finding new useful materials and processes applicable to this multifaced project. This has proved to be mutually beneficial, primarily for the reason that the contacted industries recognized motion picture production, often for the first time, as a potential consumer of many of their products. The studios have profited substantially from these contacts since they provide a wealth of advanced technical information and

Presented on April 30, 1951, at the Society's Convention at New York, by W. V. Wolfe for Herbert Meyer, Motion Picture Research Council, Inc., 1421 North Western Ave., Hollywood 27, Calif.

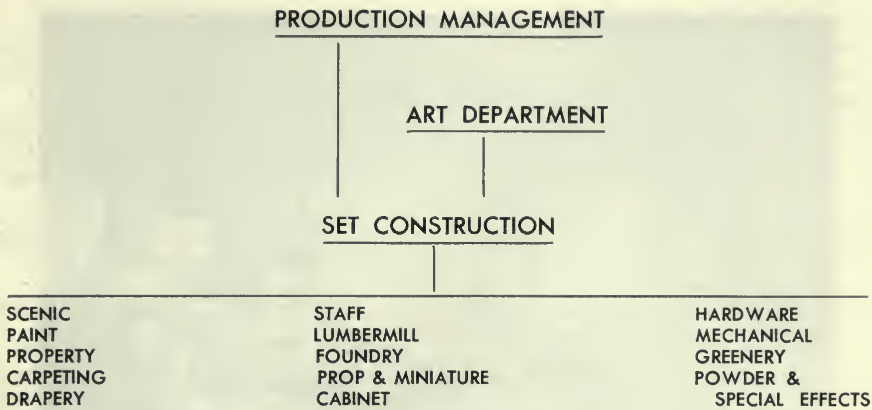


Fig. 1. Material-processing and fabricating shops and subdepartments.

experimental aid contributed by the research laboratories and the highly-developed technical service divisions of practically all those enterprises which were approached.

The set-construction department, to cope with the variety of tasks, has at its disposal an array of material-processing and fabricating shops and subdepartments which form an organized entity, as illustrated in Fig. 1.

An exhaustive description of the functions and activities of each of these shops is not possible within the scope of this paper. Our discussion is restricted, therefore, to a presentation of typical examples. Before proceeding, a few remarks on certain features affecting set-construction operations may assist in better understanding existing conditions and the reasons for their establishment. Proper conception and analysis of these furnish means for recognizing future trends and form a basis for possible development in a desired direction.

The fact that the studios should have to engage in such diversified fields of fabricating as indicated by the departmental setup, appears at first hand somewhat debatable. The economic soundness of operating such shops can be rightfully questioned, assuming that within the large industrial area of Los Angeles there are a great many fabricators who could take care of these requirements and who operate with less overhead than the average studio. It can be shown, however, that the development of such industrial facilities is only of relatively recent date and not yet comparable to that of eastern and midwestern sections of the country.

Another reason for the studios' policy of self-sufficiency in this field is the requirement of immediate availability of set-construction items. Scheduling a motion picture is controlled by many factors which, to a large degree, are not predictable. Changes in schedule are not introduced, as often assumed, by bad planning, but rather by the fact that even with the most careful and experienced preparation, last-minute modifications and delays are practically unavoidable. Production of a motion picture is, of course, a highly technical undertaking, but is interwoven with artistic and human elements which defy orthodox technical treatment. These circumstances necessitate rush orders which, in turn, require immediate availability of fabricating facilities in order to avoid expensive production delays.

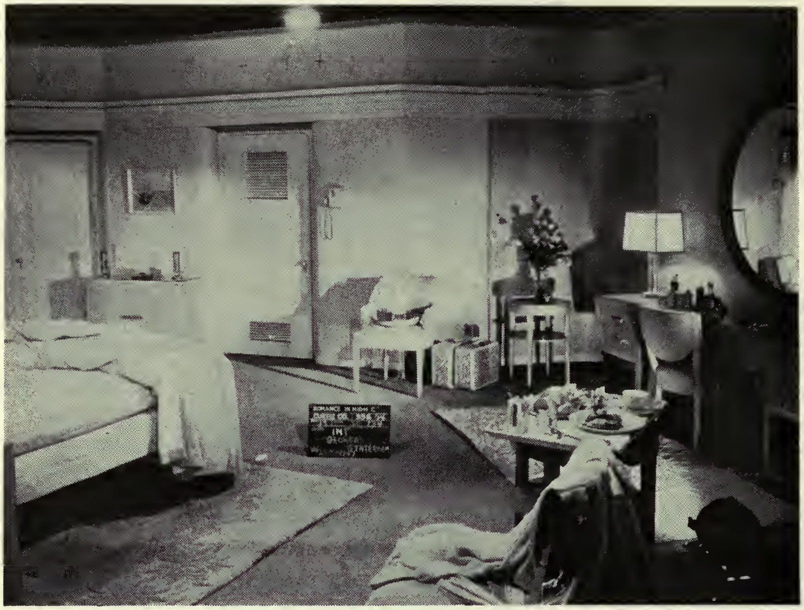


Fig. 2. Typical hard flat set.

Fig. 3. Rear view of hard flat, corner section, showing structural details.

Furthermore, it is doubtful that outside fabricators could produce some of the properties at a profit within comparative studio costs, since repeat orders are not guaranteed, quantities are small and the fabricated item does not always have a value for other markets.

One may interject that there must be a number of items of repeated usage in set construction which consequently are practically standard in size and shape. An article of this type is the brick-wall unit which is produced in large numbers in studio staff shops. There is little doubt that with industrial advancement a substantial portion of present costly studio operation in fabricating will eventually be entrusted to outside local establishments to mutual advantage.

Following is a description of activities pertaining to set construction. In view of the great variety of materials and of application methods, three main groups were selected:

I. Structural materials for sets and set properties and techniques of application;

II. Materials and methods for surfacing; and

III. Materials and methods for "special effects."

An attempt has been made to cover established practices, recent developments and to indicate trends. It was thought important in this connection also to point out objectives which so far have not been satisfactorily reached.

Part I. Structural Materials for Sets and Set Properties and Techniques of Application

Wood Products

Lumber, presswood and composition-type materials such as plywood, masonite, fiberboards and similar products, are used in considerable quantity. A typical structural unit to be found in studio set construction is the so-called "flat." Two types of flats, both used for interior walls, are practically standard items.

One, called "hard flat," is made of a multiple plywood surface backed by a wooden frame and bracings (Figs. 2, 3 and 4). It serves as a wall unit of great durability, which is reused over and over again. It is fabricated up to sizes of 4 × 12 ft and is fairly heavy.

The other type, called "soft flat" (Figs. 5 and 6), is composed of a light wooden frame over which is tightly stretched a muslin-type fabric. It was introduced originally by requests of the sound engineers for wall materials of less density than the plywood-surfaced flats.

Both types have their specific advantages and disadvantages. The present trend, which favors hard flats, is due in large measure to the successful introduction of the Peel Paste[2] technique with its improved method of recovering and resurfacing plywood flats.

There is a definite interest in an improved hard flat, lighter in weight and more resistant to scuffing than plywood. It should be free from warpage, reasonably weather resistant and permit nailing. The ideal would be a board material exhibiting all these properties, and, in addition, having sufficient strength and bulk to be used as a wall unit without requiring heavy bracings.

Plaster Casting and Staff Shop

Plaster-type materials are used in very large quantities and for a great variety of fabricating purposes. The low price of the raw materials and the simplicity of fabrication methods which may be performed without exacting and expensive mechanical equipment have made plaster casting a most important part of set-construction activities. Modern cost analysis of studio operations, however, has revealed that the excessive weight of plaster casts, which translates itself into high costs for transportation, supporting structures and rigging, causes plaster to be a highly expensive operational item. Low chip resistance, brittleness and poor weathering properties are also on the debit side.

This has prompted the search for lighter-weight materials of greater mechanical endurance, which has resulted in the introduction of plastics in direct replacement of plaster, as described in a later section.

Many direct efforts have been made to eliminate the shortcomings of standard plaster casts, aimed at improvement of plaster materials as well as fabrication methods.

Casting-plasters of highly increased tensile and impact strength, such as calcined plaster and melamine-compounded types, have not found appreciable recognition due to their much greater material cost. Art plaster, a dextrine-gypsum-type material, has been accepted for its

Fig. 4. Construction of hard flat set. Front surface of set walls presents intricate ornamental patterns obtained by novel plaster casting technique.

Fig. 5. Typical soft flat set.

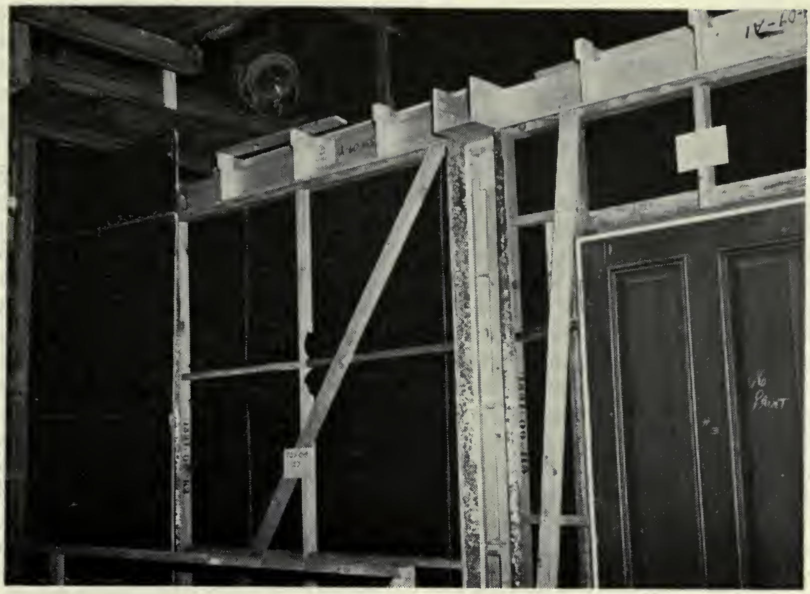


Fig. 6. Soft flat unit. Same as Fig. 5. rear view.

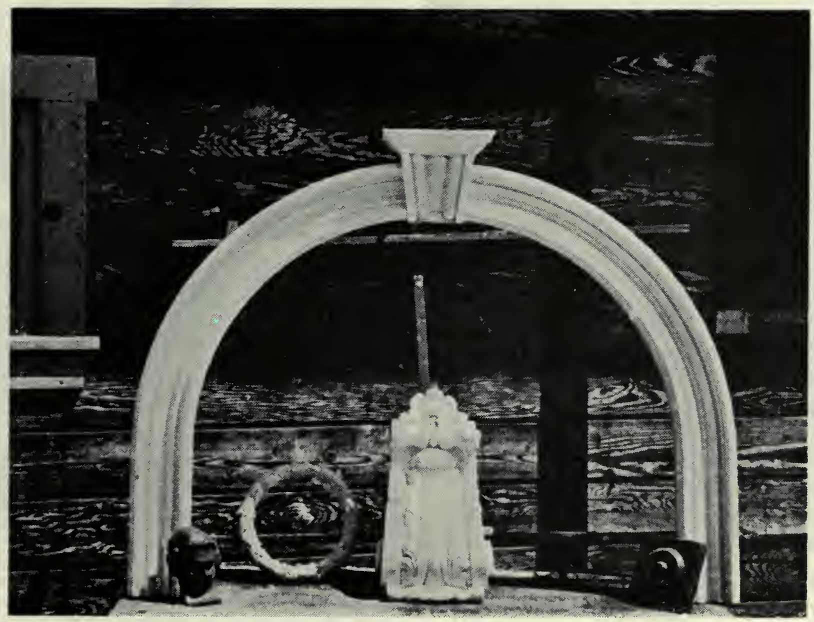


Fig. 7. Arch cast from urea-formaldehyde-reinforced plaster.

noticeably better mechanical properties (except sensitivity to humidity), since it is available at only a fractional increase in cost per pound.

Recently, the studios have found excellent use for urea–formaldehyde-fortified plaster. In the present form of application, this resin and the required catalyst are added in water solution to the plaster slurry. The greater tensile and impact strength of the resulting plaster is utilized in several ways: it permits thinner casts, which means reduction in weight; it has also been found suitable for replacing expensive wooden moldings, such as are required for the curved parts of Roman- or Gothic-type window frames; it has become a preferred material for building cornices, stairway steps and other structural units which may be exposed to excessive scuffing, marring or wear of any type (see Fig. 7).

However, the hardening of plaster through admixture of urea–formaldehyde is only effective to a certain degree. It was found that the hardening effect is practically confined to the surface of the plaster cast and that inside portions remain unchanged. This is probably due to the fact that the gypsum in the process of setting squeezes the yet unreacted urea–formaldehyde solution toward the surface. The setting of the urea–formaldehyde to a resin apparently takes place later. It is, no doubt, induced by the increase in temperature resulting from the exothermic reaction of plaster setting.

A more uniform hardening effect can be obtained by considerably increasing the amount of urea–formaldehyde added to the plaster slurry. However, this raises the material cost to an objectionable degree.

Fig. 8. Rough-surfaced stone slab, spray-cast from mixture of chopped glass fibers and plaster slurry by Paralite process.

Fig. 9. Rock column made from glass fiber-reinforced polyesters. Brick wall and stone wall units fabricated from same material.

Studies aimed at keeping the urea-formaldehyde more uniformly distributed in the plaster cast through addition of water-soluble gums or cellulosic ethers show promising results.

Hardening of plaster does not satisfactorily increase chip or crack resistance. Recent experimental work in this direction has produced improved plaster modifications through incorporation of film-forming emulsions of polyvinyl, methacrylate, polystyrene and copolymer types.

The reinforcement of plaster with fibers is generally practiced. Plant fiber, such as sisal, has been replaced in some studios by glass fiber, while others consider the higher cost and the irritating effects of glass fiber dust with disfavor.

An ingenious method of spraying plaster slurry together with short chopped glass fiber into molds, using a specially designed double-spray gun, has been developed by one of the studios. It is most advantageously applied in fabricating large objects such as rocks, brick-wall paneling and other structural items, since it permits reduction of cross section and, consequently, weight, without sacrificing strength (Fig. 8).

Mold Materials

The flexible polyvinyl-type mold has, in several studios, practically taken over the function of the glue mold for plaster castings due to its superiority in toughness, flexibility, inertness to humidity change and other properties. It also is replacing increasingly the rigid plaster mold except when relatively very large castings are being made. Here the difference in price of the mold materials and the ease of fabricating the mold may still favor plaster. So far, the thermoplastic-type polyvinyl rubber is practically unchallenged, in spite of the fact that it requires a rather critical process of heating, melting and pouring. The thermosetting type of material available for making flexible molds, such as thiocol rubber which can be worked at room temperature, is considerably higher priced and cannot be reused, so that mold failures are total losses.

Plastics and Related Materials for Structural Use

Thermosetting Compounds—Polyester Contact Resins. The most significant change that has recently affected the established routine of studio staff work was brought about through the introduction and acceptance of polyester contact resins. These compounds, activated by catalysts and accelerators, set up and cure at room temperature to yield rigid or flexible shapes of extreme mechanical strength and excellent detail fidelity. They have, so far, most closely answered the need of the studios for suitable light-

Fig. 10. Roofing shingles cast in unit of approximately 4 ft x 6 ft, made from glass fiber-reinforced polyesters.

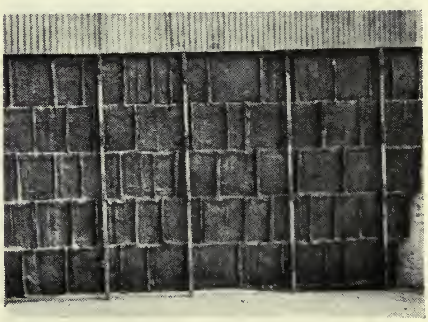


Fig. 11. Same as Fig. 10, rear view.

weight structural materials. The general technique by which they are employed consists of a casting-laminating process which combines glass-fiber mats with the resin in rigid plaster or flexible molds. Final curing to tack-free surfaces is obtained by exposing the cast to sunlight or through short heat cycles in temperature-controlled ovens. The exceptional impact and tensile strength of these casts makes it possible to reduce their thickness to a fraction of that required for plaster casts. This results in substantial savings in transporting, erecting and striking, so that in spite of the comparatively high material cost of polyester–styrene resins, their use has been constantly increasing (Figs. 9, 10 and 11).

Desirable Improvements in Polyester Contact Resins. Desirable improvements to extend the application range of these types of materials for studio work are expected in the following directions:

(a) Development of lower-priced resins: It is conceivable that progress in fully understanding the reaction mechanism of cross-linking polymers will extend the presently restricted number of relatively expensive unsaturated chemical compounds, such as alkyd types, to include less costly components possibly capable of forming thermosetting resins under proper conditions. Particular attention is pointed to the potential usability of the various unsaturated residues obtained in refining petroleum crudes. They are inexpensive and abundantly available. They form thermoplastic, low-molecular polymers when heated in presence of oxygen without appreciable loss of double bonds. Being usually of dark color limits their application in many fields. This would not, however, prohibit their extended use as structural materials in studio work, provided a simple reaction process could be developed to change them into thermosetting compounds.

(b) Development of fire-resistant-type polyesters: Although flameproof resins are commercially available, or treatments to reduce the flammability of standard types have been suggested, none of these are entirely satisfactory so far as studio experience has shown. Improvements in this direction would open additional avenues of application for these materials.

(c) Improved parting agents for flexible molds: Since monomer styrene attacks polyvinyl chloride-type mold materials, particularly at elevated temperatures, difficulties are encountered in the use of such molds for polyester–styrene casts and laminates.

(d) Development of spray technique for polyester resins: Spray techniques are being used by a number of commercial fabricators, such as boat builders. A thoroughly satisfactory method has, so far, not been developed for application to studio work. The two principal difficulties concern the control of the catalyzed resin to avoid premature gelling in the gun and in the mold, and the poor wetting properties of glass fiber which prevent satisfactory penetration of the resin into the fiber mat.

(e) Colorless, transparent casting resin of low shrinkage: Requests for such a material have long been voiced in various fabricating fields. There is a definite, although limited, need for studio application.

Miscellaneous Recent Developments in Thermosetting Plastics. Of possible substantial importance appears to be the recent advance in producing cold-setting phenolics. Their properties are sufficiently different and distinct from those of polyesters that they should find many uses to good advantage. At this point, however, practical experience is yet insufficient for their full evaluation.

A unique product employing polyester constituents has been successfully introduced for application in prop and miniature work. It consists of a special-type clay material impregnated with precatalyzed polyester–styrene. This compound can be hand formed or modeled since it has claylike properties, and can be

set and cured to a tough, rigid material by exposure to heat.

Glass-fiber sheaths impregnated with precatalyzed polyester–styrene are known to the studios. Their use has, however, not been extensive.

The recent commercial appearance of polyesters in solid form which are formulated by the user through the simple process of dissolving the solid in monomer styrene, is decidedly interesting. The advantages offered in safer storage and choice of formulation should make these resin types a welcome addition to the ones available as ready-to-use polyester–styrene liquids.

Thermoplastic Compounds. The variety of materials belonging to this group does not lend itself to simple classification. Materials such as waxes have to be included although they may not belong, by chemical structure, to the group of plastics produced by polymerization. Some of these materials are employed in fabrication methods making use of their thermoplasticity, others are not. In the first instance, their thermoplastic properties are a direct advantage, while in the second case this property is either ignored or presents even a disadvantage rather than an advantage.

Of the many materials used quite extensively by the studios, the following were selected as examples:

(a) Waxes: Natural and synthetic waxes have been found to offer unique properties in the fabricating of a number of different studio properties. Their peculiar translucency and surface reflectivity make them ideal for imitation of objects which depend upon these specific qualities for convincing photographic reproduction. The ease with which waxes can be colored or pigmented is another favorable quality.

An outstanding field of potential application, not yet fully exploited, is that of marble imitation. It is repeated for emphasis that adaptability of materials for studio work depends not, in the final end, upon visual, but on photographic judgment. There is no material known comparable to waxes which conveys, in photographic reproduction, equally the peculiar, complex impression of marble as it is stored in our memory. Fairly satisfactory marble effects are frequently obtained through surfacing objects such as walls or panels with a marble-patterned paper, which is a simple and inexpensive process. This becomes, however, quite difficult when the surface of the object is of a compound shape or if the object has fine ornamental details and undercuts. Certain types of columns are good examples in this respect. Casts made of white microcrystalline wax, impregnated with dyes and pigments for imitation of veins and irregular strata, produce most striking effects.

Different techniques for fortifying waxes to increase tensile and impact strength, through adding small percentages of ethylcellulose, low polymer-type polyethylene and other ingredients, make it entirely feasible to consider waxes for much more general structural use in competition with the already discussed thermosetting materials. Such modified wax materials are already successfully employed by commercial fabricators in the manufacture of window-display models, dolls and ornamental figurines. They can be used as such, or in combination with reinforcing materials such as fiberglas. A unique process for such purposes is slush molding, wherein the molten wax is poured into a closed female mold. After pouring back the excess, a hollow cast remains. The wall thickness of the cast can be controlled through adjustment of the pouring temperature.

The relative flammability of wax materials presents a serious hazard during the process stage and in the finished product. The necessity of pouring the material at high temperatures contributes, in addition, to the dangei of occupational hazards.

(b) Thermoplastics for hot-drawing techniques: This standard process,

which requires only a minimum of simple and inexpensive equipment, is favored in studio prop and miniature shops for fabrication of a variety of items. Among these are helmets, armors and similar historical commodities. The imitation of the required metallic properties is accomplished through surface treatment. In film productions of stories with a medieval historical background, availability of this process presents a highly appreciated contribution to economy and, not least, to comfort for the wearer due to the lightness in weight.

Thermoplastic sheet materials, used for hot drawing technique, are methacrylates, ethyl cellulose and cellulose acetate. Cellulose triacetate, recast from photographic film waste, and extruded cellulose acetate butyrate sheets are also presently under consideration.

(c) Cellulosic materials specialties: A commercially available, highly porous material in sheet form, consisting of cotton flannel impregnated with cellulose nitrate and a fire retardant, has been found quite useful for fabrication of lightweight articles such as boat hulls, cylinders, shells, tubes, guns and clubs. The original dry material is impregnated with a solvent and becomes entirely flaccid. In this condition it can be readily formed around or in a variety of regular or irregular shapes. Upon evaporation of the solvent, the material becomes rigid, retaining the shape formed during the molding operation.

Similarly, it is possible to impregnate plain felt, gauze or paper with a solution of cellulosic materials and to obtain a practically equivalent result.

Due to the fire hazards involved, suggestions have been made to replace the cellulosic components with polyvinyl resins. Some of the recently-tested formulations appear to work satisfactorily.

(d) Cellulosic materials for translucent screens: The use of cellulose acetate and ethyl cellulose in the fabrication of large seamless sheets of up to 30 × 36 ft for background process screens, and of even considerably larger sizes for translucent scenic backings, are rather ingenious developments that originated in Hollywood studios. Such sheets are fabricated by hand spraying a carefully blended mixture of cellulosic materials, plasticizers and solvents of varying volatility against a resin-impregnated canvas sheet serving as a matrix. This matrix is normally mounted overhead in a horizontal position. The spray operation is continued until a sheet of sufficient uniform thickness is obtained. The finished sheet is stripped off the matrix and mounted with uniform tension onto a vertical frame. The required diffusion is obtained by hand spraying the sheet surfaces with a similarly formulated cellulosic dope, as was used for making the sheet, to which suitable diffusing agents, such as zinc stearate, silica gel or others are added in uniform dispersion.

(e) Use of other plastic materials: From this report so far, it becomes evident that the predominant use of plastics and other materials for structural purposes in a broader sense, centers in the fabrication of rigid articles and units. This accounts for the relatively small employment of vinyl-type materials in this field.

Fabrication of flexible commodities is mainly represented by sponge and foam rubber. Some of the studios have fully equipped facilities for processing such materials and have excellent knowledge in formulation and handling.

The technique of using Plastisols has not yet found entry into studio shops. Cost of materials, initial equipment and operations are considered fairly prohibitive, since the studios are not concerned with mass production. Artificial plants and leaves are now commercially produced from polyvinyls by a Plastisol technique. Such a process, if applicable to the manufacture of bulk foliage, would be of extreme importance and interest to this industry (Fig. 12).

Cold slush molding, using natural rubber latex and porous (plaster) molds,

Fig. 12. Plastic plants and foliage fabricated from polyvinyl Plastisols.

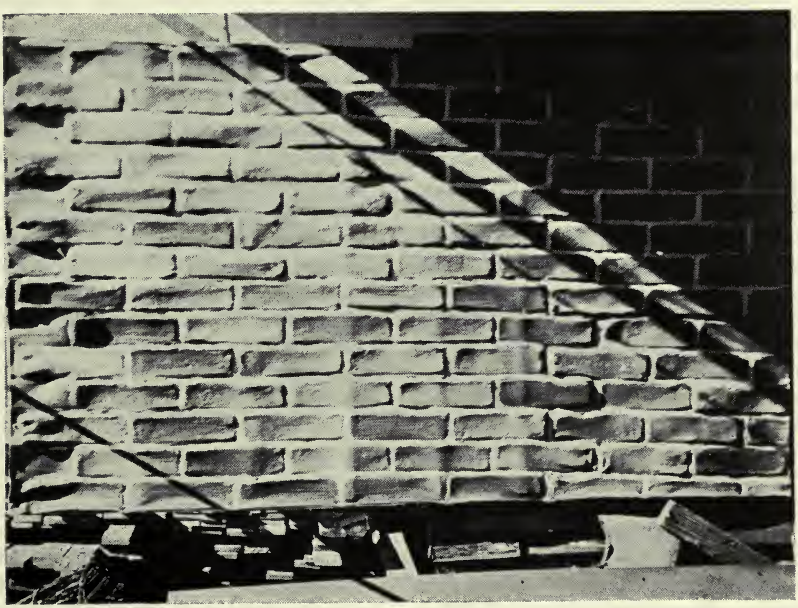


Fig. 13. Unfinished brick wall made from "Thermold."

has, so far, not gained much notice, although it appears a well-suited process for studio application due to its simplicity and the fact that through varying the amount of clay fillers, lightweight articles ranging from flexible to rigid can be produced.

An important and unique use of polyethylene resin is in the construction of compound-shape stair-rail easements. The stair rail is first cast straight. By reheating selected parts to about 250 F, they can be bent and set to any desired shape.

Development Trends in Thermoplastic Materials.

(1) Thermoplastics, so far, have not been seriously considered or used as components in bulk structural materials. This possibility appears quite intriguing for the reason that a number of such materials, like asphalts, petroleum resins and pitches from various sources, are amply available at low cost. The fact that thermoplastics can be reused or reshaped are added inviting properties.

Their greatest deficiencies lie in lack of tensile strength and in their high brittleness which those exhibit that possess a softening point sufficiently high for studio requirements.

It appears possible that these undesirable properties can be sufficiently overcome through compounding with a relatively small percentage of rubber-type materials. It may be practical to fabricate sheets of varying stiffness through impregnation of textiles and other supporting materials with these modified thermoplastic compounds or to obtain them in calendering operations. One commercially available product of this type, although not known in composition, has found use in the making of lightweight, brick-faced wall units (Fig. 13). This material is supplied in rolls. When heated to an approximate temperature of 140 F, it becomes sufficiently pliable to respond to hand or low-pressure molding. Upon cooling, the molded material will regain its rigidity. The original commercial function of this material is to serve in the fabrication of dress forms which can be molded directly by hand over the human body due to the relatively low temperature required.

It should not be assumed from the above that thermoplastic materials are considered a cure-all for the solution of the many structural material problems confronting this industry. However, an open-minded approach to the possibilities and advantages these materials unquestionably offer may pay considerable dividends. It should be kept in mind that deficiencies in certain properties, which would condemn such materials for permanent structures, may not eliminate their usability for temporary structures in studio work.

(2) An entirely novel approach, the practicability of which still awaits considerably more testing, suggests the use of unsupported polyvinyl sheetings as building materials for relatively large props and structural units. These could be cut in accordance with designed patterns and joined by a heat sealing technique. For use, the finished article is inflated with air. The advantages offered are low weight and ease of transportation since props of this type can be deflated. This technique would also, of course, be practical only for a limited range of structural set items.

Part II. Materials and Methods for Surfacing

The activities related to this subject are performed by the paint shops and the scenic departments. It is a field in which the well-known techniques of brushing, spraying, dipping and troweling are applied with a variety of materials for ornamental and functional use too large to be described in detail.

It includes oil- and water-base paints for outdoor and interior use, varnishes, lacquers, sealers, primers, thinners, solvents, protective coatings, flameproofing compositions, water repellents, flatting agents, pigments and fillers, surface-active agents, antistatic agents, wood preservatives, specialty coatings such as multicolor paints and skidproof paints, metallizing paints, conductive coatings, heat-absorbing and reflecting coatings, peelable coatings, adhesives, putties and caulking compounds, paint removers, floor maintenance compounds, cleaning compounds and a host of others.

This general classification should suffice to convey an impression of the variety of materials belonging to the broad fields of surface treatment in which the motion picture industry is interested.

Each paint shop has ample facilities for testing the constant flow of new commercial products to stay abreast of the rapid technical developments in all branches of interest.

While it is not intended to describe surfacing materials and techniques in any detail, a brief consideration of some rather unique studio applications may be of interest.

Outdoor Backings

To the standard implements of studio facilities belong large rectangular-shaped pools which permit staging of any kind of water scene on the studio lot. The proper pictorial background, whether horizon and sky with cloud effects or other suitable scenery, is furnished by a hand-painted backing. The supporting structure for this painted backing is a wall made of plaster, concrete or wood. It presents a smooth, plain surface facing the pool. The background scenery is either painted directly onto this surface or the surface is first covered with canvas to which the paint is then applied. Outdoor backings of this type are made up to sizes of 60 ft in height and 300 ft in length (Fig. 14).

Surface coatings and paints suitable for this specific application require a high degree of weathering resistance. The use of polyvinyl derivatives which, when incorporated in a water-base paint, are capable of forming a tough, continuous film upon drying, has been recognized as an excellent means of preventing cracking and chipping of painted backings, even under prolonged exposure.

Foliage Treatment

The studio demand on cut branches or foliage for scenic effects is extremely large. Wilting and drying not only cause problems of fire hazards, but also necessitate continuous costly replacements.

Two practical methods have been developed and are in use, both capable of preserving foliage for repeated use and of rendering it effectively flameproof.

One is a treatment by which the foliage is impregnated with a concentrated solution of calcium chloride in large studio-designed vessels under application of vacuum and pressure (Fig. 15). The treated foliage loses its natural color, which is artificially replaced by means of spray painting with a coating containing a suitable dye and a flame retardant.

In the other method, the foliage is simply hand sprayed with a formulation of natural rubber latex to which pigments and flame-retardant fillers have been added.

Both methods have proved satisfactory in reducing fire hazard and preventing drooping and wilting effects on leaves and branches by supplying a type of mechanical support to the treated foliage.

Developments and Trends

Modified phenolics formulated as sealers and top coatings have been found most useful for stage-floor maintenance and as protective coatings on plywood surfaces.

Fig. 14. Outdoor backing with built foreground set.

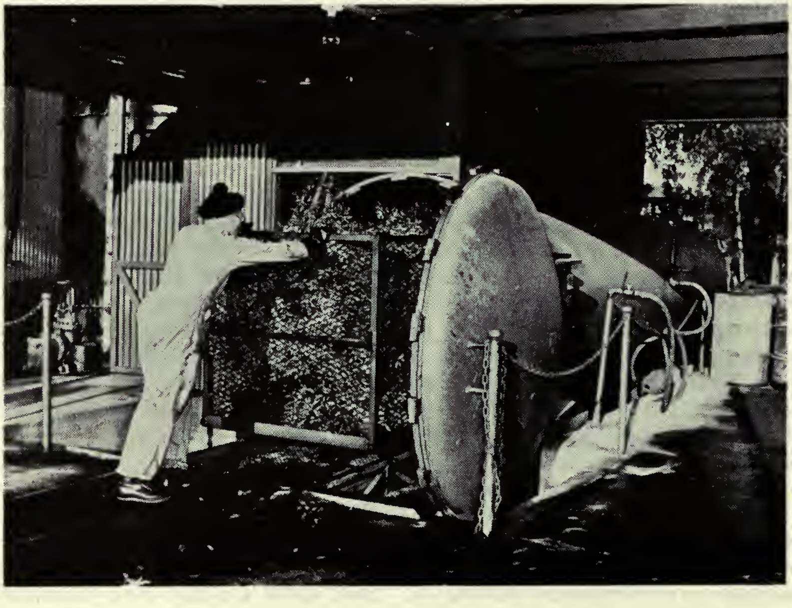


Fig. 15. Plant and equipment for preserving and flameproofing natural cut foliage.

Hot spray lacquers are being tested for the advantages they offer in yielding heavier coatings.

A trend toward water-base, latex-type paints is becoming quite evident and has just recently received considerable acceleration through the introduction of several polyvinyl-type products of greatly improved flow characteristics, stability and hiding properties.

Part III. Materials and Methods for "Special Effects"

Studio terminology combines under "Special Effects" a large variety of items, materials, equipment and processes which, selected and developed, sometimes with amazing ingenuity, aid in realistically imitating natural phenomena for photographic reproduction which otherwise could be considered only at prohibitive expense or with impossible hazards. Some of the effects described belong to prop and miniature shop activities or those performed by the staff shop.

The special effects department is constantly confronted with requests for the apparently impossible and actually creates new effects almost in every day's work. It is, therefore, possible to discuss only a number of those effects which have become standard parts of motion picture practice. Since this paper is written primarily from the viewpoint of one interested in materials, the purely mechanical phase of this field will also be omitted. It should, however, be mentioned here that the efforts and merits of the special effects departments in engineering developments are outstanding in quality and quantity. Wind and wave machines, rain-producing equipment, explosive devices, instruments for any conceivable sound effect and innumerable other means for producing specific phenomena in any wanted strength and modification give ample testimony to the inventiveness and mechanical skill of those engaged.

Fog Effects

In producing fog effects, the potential scope of fog-producing reactions, materials and processes is considerably limited since toxic and corrosive ingredients are prohibited. Other factors reducing the choice of materials are odor, lacrimating and otherwise irritating effects on personnel, and attacking properties on paints, lacquers, textiles and the like.

The most desired qualifications for fog effects are high volume, density, stability and, partly related, ease of stratification.

The studios differentiate between chemical and other fogs. Chemical fogs are mainly those obtained by the interaction of amines and acids, but also included are titanium chloride, sulfuric anhydride and other hydrolyzable compounds. They are known to produce fogs of ideal density, so far not obtainable with any of the other materials. Corrosive properties, however, restrict them to occasional outdoor use.

Oil fogs are most frequently used, although their density and stability are not too satisfactory except where large-size generators are employed. Oil fog is produced by studio-designed equipment, based on either atomizing oils selected from suitable petroleum fractions at room temperature or on vaporizing the oil by heating it to the required temperature. The latter process is quite superior where fogs of large volume and density are required. It may be engineered by the simple use of electric hot plates or with complicated heat guns from which the oil is ejected by air pressure through nozzles after passing an arrangement of heat coils. Natural and dry ice are employed to increase density and stability of the formed fog cloud.

Developments in this field are aimed at improved equipment and simplification of producing methods. Recent

Fig. 16. Interior stage set with dress snow using crushed rock.

Fig. 17. Interior stage set with dress snow using silica gel.

experimentation with emulsified oils is quite promising. Investigation of humectants, such as glycol derivatives, with incorporation of inorganic salts such as ammonium chloride, point to other interesting material sources.

Smoke Effects

It is probably surprising to learn that a completely satisfactory method of producing black smoke is still not available or known to the studios. Of the two methods most frequently employed, one consists of the use of commercially available smoke candles. These usually contain hexachloroethane, among other ingredients, and are disliked due to odor and corrosiveness of the smoke by-products.

The other method makes use of a mixture of diesel oil with 30 to 40% carbon tetrachloride which is ignited in open vessels. The function of the carbon tetrachloride is to induce and maintain conditions favoring incomplete combustion. Attempts to replace carbon tetrachloride with organic halogen derivatives of similar functional properties, but yielding less toxic decomposition products, have so far failed.

A limited, but occasionally pressing demand exists for colored smokes. Commercial smoke candles are available for this purpose but their performance is quite poor. Further research in aerosol technique, although so far not successful, may yet lead to better methods.

Indications are that military basic research undertaken during the last war has advanced the knowledge of conditions under which controllable fogs and smokes can be produced to a remarkable degree. Much of this work still awaits declassification.[3]

Snow Effects

Artificial snow for studio use has two distinct classifications. One includes materials useful for dressing stage or location sets with snow effects which are accordingly known as "dress snow." The other applies to material suitable for the imitation of falling snowflakes, which consequently is termed "falling snow."

Materials for falling snow have to be fairly light, fluffy and of a particle size not less than $\frac{3}{8}$ in. to properly convey photographically the impression of falling or drifting snowflakes.

The same type of material used for falling snow may also be satisfactory for dress snow. However, dress-snow materials generally consist of heavier, crystalline, salt-type compounds such as gypsum, rock salt and the like (Fig. 16).

A recent interesting development concerning dress snow is a method by which a solution of sodium silicate and of a mildly acidic or alkaline compound is brought together to form silica gel in a reaction chamber consisting of an elongated cylindrical tube. The silica gel is extruded at the far end of the tube and chopped into snowlike fragments by a propeller blade. This process produces dress snow continuously. The equipment is mounted on a carriage which permits the dressing of sets and locations with a minimum of manual labor. This snow material is particularly capable of rendering realistic footprints and wheel tracks (Fig. 17).

Another material, also lending itself to satisfactory rendition of snow impressions, is so-called "snow plaster" which has been in use by the studios as dress snow material for a long time. This product is specially produced casting plaster to which blowing agents have been added which are activated as soon as the plaster slurry is mixed. The resulting cast is a highly fluffy product which can be broken, crushed and powdered on fairly light impact.

The oldest-known stand-by for falling snow material is a special type of cornflakes. They are either thrown by hand into the air current of fans or sifted from overhead through sieves onto the stage. Rubber foam, feathers, heating of metaldehyde, perlite, etc., have also been used more or less successfully for this.

Fig. 18. Equipment for producing falling snow with foaming agents.

A novel process of great merit developed in one of the Hollywood studios utilizes foaming agents in concentrated solutions such as have been employed in fire-fighting equipment. The solution is ejected in continuous operation through a rotating perforated drum mounted centrally in front of a large fan. The foam is propelled in controllable flake size over a relatively large area. Modification of fan speed permits a wide range of phenomena from light or dense plain snowing to blinding snow storms (Fig. 18).

The snow dressing of trees, slanting surfaces, window sills and the like requires, with present methods, a large amount of manual effort and is, therefore, quite costly. A flocking procedure in some form, with suitable flock materials, may be a future answer to this problem.

In general, it can be stated that considerable savings would result if more suitable mechanical equipment for snow dressing and equally for removal of dress snow were available.

As far as snow materials are concerned, none of the presently used compounds are entirely satisfactory. Color photography prohibits the use of impure salt materials. Some of the compounds affect clothing, paints and lacquers. Again, others lack stability in storage or while being exposed to outdoor weather conditions.

Cobwebbing Effects

Spider-web imitation, a frequent scenic requisite for mystery-type stories is usually accomplished by spraying rubber cements using spray guns or special equipment with rotating ejectors for spinning the thread. Careful formulation is required to obtain realistic effects. Reasonable stability and nonflammability of the formed web are desirable. Solutions of polyvinylidene chloride appear best suited. A quick solvent release through proper selection of solvents minimizes fire hazards.

Breakaway Materials

This designation is applied to structural materials which, due to light weight, brittleness and other selective properties can be fabricated into fight props, such as clubs, sticks, gun butts, bottles and furniture and which on impact break easily without causing pain or injury. Such materials are also useful in the construction of buildings, walls and any type of structural unit which, in line with the story, collapses on the actors as the apparent result of catastrophies such as earthquakes, shipwrecks, bombings, etc.

A further frequent use of this type of material is for the realistic replacement of window glass and mirrors. The hero or the villain involved in a barroom fight of an action-filled Western thriller may then endure safely the experience of being hurtled bodily through such props.

The use of balsa wood for breakaway opaque objects dates back to the beginning of the motion picture industry. However, this material is quite expensive and is limited to typical woodworking operations. Plaster extended with lightweight fillers such as vermiculite, perlite and ground Styrofoam has the advantage of being workable in molds. Foamed plaster, like the snow-plaster material mentioned earlier, is used more extensively.

Just recently, commercially available gypsum, with a foaming agent added, has been found to permit the fabrication of porous, low-density molds particularly suitable for metal casting. The plaster slurry is beaten with a disc-like stirrer blade to entrain air and cause foam which can be made to consist of a very large number of bubbles of small, practically uniform size, evenly distributed through the slurry. Depending upon the amount of air entrained, the resulting cast exhibits different degrees of density. This material is also useful for casting breakaway props.

Various plastic compositions capable of being foamed in place have been tested without, however, so far finding suitable materials or processes. The only materials of proven reliability during the processing stage are the arylisocyanates, which are, at present, out of practical reach due to their high cost. Developments in this field of foamed plastics are eagerly awaited by this industry as their potential usefulness in many applications is well realized.

"Breakaway glass" can be made from a number of plastics, all thermoplastic by nature. The properties of these special compounds are quite tricky and include particularly a grade of brittleness which renders the material practically useless for any other fabricating purpose.

Breakaway glass props (Fig. 19) are made by slush molding or casting. The resins used should be preferably water white and transparent. The pour point should not be higher than 275 F; the softening point not less than 100 to 125 F. The resin must be free from cold-flow tendencies. It has to be friable and should readily break into fragments with completely dull edges.

An ideal resin for this purpose was a specialty product manufactured by internally plasticizing styrene with isoprene during the process of polymerization (reversed rubber type). Unfortunately, this material is not produced any more for the present. Other materials quite

Fig. 19. Breakaway glass props.

useful are special phenolic resins, arylsulfonamide–formaldehyde resins and a low polymerized styrene type plasticized with Aroclor.

In instances where presence of color is not prohibitive (colored bottle glass), rosin can be used as an inexpensive, readily available material.

The casting of panels serving as windowpanes is accomplished by pouring the resinous melt onto a sheet of cellophane fastened to a wooden frame. The heat of the resin, upon contact, causes the cellophane to shrink and to furnish a taut, wrinkle-free surface. Cellophane, well known as a mold-release agent, permits safe separation of the highly breakable cast from its support. One studio uses liquid mercury as a casting surface. Some of the liquid fluorohydrocarbons of high specific gravity and chemical inertness have proved experimentally useful for this purpose.

The report given in the foregoing is by necessity sketchy. It has also been unavoidable to omit a number of other departments and their important and interesting activities and to by-pass development work in various phases of motion picture production of a non-photographic nature which this industry continuously performs. It is intended to cover some of these neglected subjects in a later paper.

The following list of estimated average yearly requirements of the Hollywood motion picture industry on some of the materials discussed may be of general interest:

Plaster of Paris		3,000 tons
Casting plaster	85%	
Art plaster (plaster plus dextrin)	10%	
Hard wall plaster (calcined or resin additives)	5%	
Fiberglas		25 tons
Natural fibers (mainly sisal)		50 tons
Paint thinners		40,000 gal
Shellac		40,000 gal
Lacquer thinners		35,000 gal
Paint lacquers		11,000 gal
Flat paints—oil base		32,000 gal
Flat paints—water base		15,000 gal
Paint enamels		6,000 gal
Varnishes		4,000 gal
Whiting and titanox		20 tons
Earth pigments and dry colors		95 tons

Oil putty	6 tons
Spackling putty	6 tons
Denatured alcohol	40,000 gal
Turpentine	10,000 gal
Linseed oil	2,500 gal
Carbon tetrachloride	7,000 gal
Acetone	2,000 gal
Kerosene	10,000 gal
Stearic acid	2 tons
Floor wax—liquid	3,000 gal
Floor wax—paste	3,000 gal
Floor-cleaning compounds	25 tons
Soap and detergents	17 tons
Bronze powders	2 tons
Mold glue (gelatin)	10 tons
Flexible mold materials (polyvinyl derivatives)	25 tons
Polyester-type plastics	75 tons
Lumber	20,000,000 board ft
Plywood	2,000,000 sq ft
Presswood	2,000,000 sq ft
Fiberboard	2,000,000 sq ft
Textiles for backdrops, cycloramas, etc. (canvas, cheesecloth, etc.)	2,000,000 sq ft
Textiles for diffusion cloth (canvas, denim, nylon, etc.)	500,000 sq ft

According to the 1948–1949 *Motion Picture Almanac*, there are 276 different industries, arts and professions involved in the making of a feature. This same source lists the costs of "sets and other physical properties" for an average production budget as representing 35% of the total production cost.

The *Film Daily Year Book 1950* publishes a figure of $62,874,000 covering Hollywood's 1949 bill for supplies, including maintenance costs.

These few statistical estimates and facts may directly and indirectly sustain the statements made in the introductory part of this paper emphasizing the importance and the extent of the nonphotographic phases of motion picture production.

References

1. Barton H. Thompson, "Present and proposed uses of plastics in the motion picture industry," *Jour. SMPE*, vol. 43, pp. 106–114, Aug. 1945.
2. W. F. Kelley and W. V. Wolfe, "Technical activities of the Motion Picture Research Council," *Jour. SMPTE*, vol. 56, pp. 178–196, Feb. 1951.
3. *Handbook on Aerosols*, U. S. Atomic Energy Commission, Washington, D. C., 1950.

Improved Kodachrome Sound Quality With Supersonic Bias Technique

By JAMES A. LARSEN

By simultaneous application of signal frequencies, d-c noise reduction bias and "supersonic" a-c bias to a variable-density light valve, it is possible to make direct recordings or electrical prints on Kodachrome with very low intermodulation distortion. This technique permits the use of a higher transmission with a resulting increase in sound output of at least 6 db.

Electrical printing of Kodachrome sound tracks without the use of high-frequency bias has been commercially available—at least, on the West Coast—for about two years. Intermodulation recordings made under these conditions indicated that for a modulation level at 80% of clash,* the intermodulation distortion was relatively high—in the vicinity of 50% at densities that gave a usable volume. The reason that acceptable recordings were possible under such high intermodulation distortion was that the recording level was kept down allowing only an occasional peak to reach into the 80% or higher modulation level. This, of course, limited the level that it was possible to put on the Kodachrome electrical print.

The advantages of "electrical printing" or re-recording printing of 16-mm sound tracks have been pointed out in an article by John G. Frayne.[1] Another article by C. R. Keith and V. Pagliarulo[2] pointed out the advantages of using a high-frequency a-c bias in making black-and-white release prints using a direct-positive variable-density track.

The method described herewith is a modification of the above-described methods of electrical printing and high-frequency bias direct-positive variable-density recording. In the present application, a high-frequency (24-kc) bias is applied simultaneously with signal frequencies and d-c noise-reduction bias to a variable-density light valve in the production of a Kodachrome sound track.

This method produces Kodachrome prints having a higher output level and a greatly reduced intermodulation distortion of about 8%. This is equivalent to a harmonic distortion of approximately 2%. In addition, greater density latitude or processing tolerance is obtained.

The reason for the high intermodulation distortion in the old electrical printing process without high-frequency bias and its reduction by the new method

Presented on May 4, 1951, at the Society's Convention in New York, by James A. Larsen, Academy Films, P.O. Box 3088, Hollywood, Calif.

*Clash is the signal level into the light valve at which the light-valve ribbons just touch, or cross if they are not coplanar.

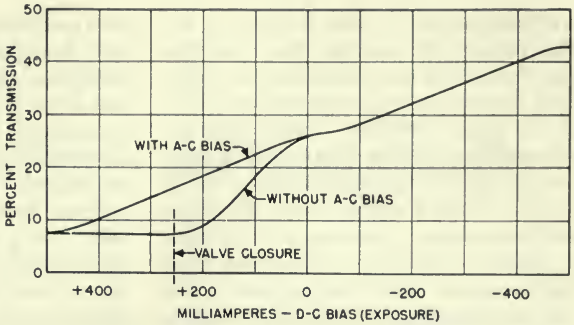


Fig. 1. Transmission-exposure curves.

using high-frequency bias can be seen by a study of the transmission-exposure curves shown in Fig. 1. In the lower curve, the large "hump" or lack of straightness is obvious. The straighter this curve, the better will be the reproduction of sound and the lower the intermodulation distortion. The application of 24-kc bias to the light-valve ribbons at approximately 200% modulation level has the effect of straightening out this curve of transmission vs. exposure as shown in the upper curve of Fig. 1. The large hump is removed and the remaining curve is nearly straight. Under these conditions, intermodulation distortion (at the same level of audio modulation, namely 80%, and at the same density of the unmodulated track without noise reduction) was reduced from a value of 56% without 24-kc bias to a value of about 8% with 24-kc bias. This very large reduction in intermodulation distortion is due entirely to the straightening out of the transmission-exposure curve of Fig. 1. Comparative listening tests on musical recordings made with and without a-c bias confirm the results anticipated by study of the transmission-exposure curves and the intermodulation curves of Fig. 2.

It was found desirable to reduce the spacing of the light valve from the standard spacing (for 16-mm valves) of 1.0 mil to 0.5 mil. Since the light valve resonates or is most sensitive to frequencies between 8,000 and 9,000 cycles, it takes a large voltage of 24 kc to drive the light-valve ribbons to 200% modulation. Approximately 12 v of 24 kc was required. The 24-kc signal was obtained from a standard Model 200-A Hewlett-Packard audio oscillator. The 24-kc level is set by measuring the output voltage of the oscillator with a vacuum-tube voltmeter, once the relation between per cent modulation and voltage has been established.

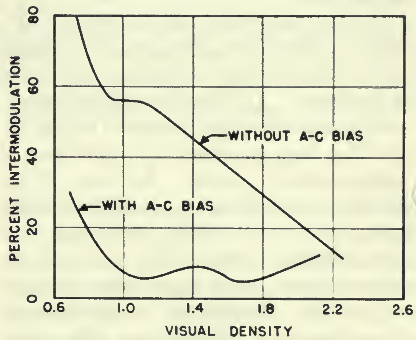


Fig. 2. Intermodulation curves.

When the light-valve ribbons are modulated 200% by the high-frequency bias, considerably more d-c bias is required to produce a given amount of noise reduction. The d-c bias must be sufficient so that, for silent passages, the light-valve ribbons are overlapped to the point where the peak amplitude of the 200% modulation of the high-frequency bias slightly opens the ribbons. Referring to Fig. 1, it will be noted that with-

out high-frequency bias, 250 ma of d-c bias reduces the average film transmission from 27% to a minimum of 7.5%. This is equivalent to approximately 10.2 db of noise reduction. With high-frequency bias, 250 ma of d-c bias reduces the average film transmission from 27 to 16.5%. This is equivalent to 4.3 db of noise reduction. Consequently, in order to obtain 10 db of noise reduction when high-frequency bias is being used, a d-c bias of approximately 450 ma would be required.

The two principal advantages of this method of electrical printing with a 24-kc bias over previous electrical printing methods are: (1) greatly reduced intermodulation distortion as shown in Fig. 2; and (2) a large increase in volume from a variable-density track. In fact, it is possible to produce a variable-density track, using 24-kc bias, with very low intermodulation distortion and with a higher volume level than from a standard, fully modulated variable-area track. Another less obvious advantage is the much greater latitude of Kodachrome densities possible when using this method. If an arbitrary value of 10% intermodulation for an 80% modulation level is accepted as a practical operating condition, then the density range over which the intermodulation is 10% or less is between a visual density of 0.95 to 1.90 (in the unmodulated area without noise reduction). In other words, any Kodachrome density between 0.95 and 1.90 will give a track with less than 10% intermodulation. Of course, the density of 0.95 will give much greater volume than the 1.9 density and is therefore to be preferred. The relation between intermodulation distortion and per cent total harmonic distortion is approximately 4:1, so that 10% intermodulation distortion equals about 2.5% total harmonic distortion which is considered very good from a 16-mm Kodachrome film reproduction.

References

1. John G. Frayne, "Electrical printing," *Jour. SMPTE*, vol. 55, pp. 590–604, Dec. 1950.
2. C. R. Keith and V. Pagliarulo, "A direct-positive variable-density recording with the light valve," *Jour. SMPE*, vol. 52, pp. 690–698, June 1949.

Tape Transport Theory and Speed Control

By J. R. MONTGOMERY

Absolute speed control can be achieved only with a fixed or recorded reference. Reasons include physical properties of tape and mechanical properties of tape transport. If tape properties can be accepted as they exist, the mechanical theories of tape transport must be thoroughly investigated. This paper is a résumé of the pertinent and sometimes little understood phenomena of tape transport and a report of the limits which these theories have achieved in practice.

IN THE LONG HISTORY of man's attempts to record the sounds he hears no problem has required more intensive research or provoked more discussion in technical circles than the efforts to control both the instantaneous and long-term speed of the recording medium. The requirements of the radio broadcast industry created the impetus necessary to numbers of manufacturers and engineers who succeeded, after concerted efforts, in designing transcription turntables of sufficient quality to satisfy the minimum requirements of the broadcasters. The problems of rotating a surface at uniform speed were serious enough to evoke the wholehearted efforts of many of our highest-caliber scientists.

Until a very few years ago most efforts to develop magnetic recording were conducted abroad. Indeed, most early, American tape recorder designs could be traced generically to the German "Magnetophon." The magnetic recording art captured the imagination of a segment of our engineering profession, but even more so, of our general population. As a result of this interest and the fact that the medium itself was no more perfected than the equipment necessary to utilize it, the pressure for production caused hurried engineering and, in too many cases, insufficient research into the underlying theories of tape transport.

The last two years have seen a shift toward sounder engineering. The properties of the medium are now stabilized and, for the most part, understood. Standards of measurement and dimension are more nearly established. The medium is accepted for use in its logical applications with general enthusiasm. Now we find ourselves in a position of having to return to a more fundamental philosophy of engineering to solve certain problems which have been clouded from view by the necessities of satisfying the initial demand for equipment. One of the greatest problems, as first presented by the broadcast industry and, of late, by the requirements of telemetering and other special applications, has been that old bugaboo *speed control*. This becomes understandable when one considers the proportionate numbers of moving parts in a magnetic recorder as compared

Presented on May 4, 1951, at the Society's Convention in New York, N. Y., by J. R. Montgomery, J. R. Montgomery Engineering Co., 1648 W. Haddon St., Chicago 22, Ill.

with a disc recorder or playback table. One additional factor not seriously considered by most designers was the concept of tape as an elastic medium.

The general term *speed control* actually includes both long-period timing and instantaneous speed variations known as "wow" and "flutter." One of the odd facets of magnetic recording is the seeming ease with which moderate flutter can be produced. The methods necessary to idealize this performance are much more elusive. Speed control is relative to tolerances. The only known methods of controlling tape timing to milliseconds are by use of a fixed or recorded reference such as a recorded signal to operate a selsyn or other form of control over machine speed. If these tolerances are required, such complex and expensive methods are probably the best solution available today. If the tolerances required are not closer than plus or minus a tenth of a second, the problem may be solved by purely mechanical methods, giving due consideration to the properties of the various recording tapes and their limitations.

The analysis of design theories and problems in magnetic tape recording may be arbitrarily divided into the following categories:

The Recording Medium,
Capstan Drive,
Tape Supply,
Pressure Pads—Pro and Con,
Take-up Design, and
Integration of Design.

The Recording Medium

Two types of tape are generally available, each having its own advantages and disadvantages. Paper-based tape has not been popular for professional use due mainly to surface finish. In order to get satisfactory signals from paper tape, pressure pads must be used to insure intimate contact of the oxide coating with the gaps of the magnetic transducers. This is considered a disadvantage on broadcast equipment due to increased head wear. In addition, the measured signal-to-noise ratios are slightly inferior when using paper-based tape. However, proper machine design can produce results from paper tape comparable to the average result now achieved with plastic tape on quality equipment.

Paper tape has one distinct advantage for accurate long-term timing. It is not seriously affected by tension or humidity in such a manner as appreciably to change its length. Where the values of noise obtained from paper tape are acceptable, the speed-control problem is much simplified. In those applications where plastic-based tape is required, one must consider the elasticity of the medium and the effects of heat and humidity coupled with tension. Such tape, when wound tightly in a moist atmosphere and then dried thoroughly, may become completely useless due to the stretching, warping, and multiple breakage which may occur while the tape remains in storage on the reel. These effects indicate the need for humidity control when close timing is desired. When the humidity is kept within a few per cent of a nominal, no appreciable errors should exist. Errors can exceed 5%, with a 20% to 30% differential in humidity. In addition, the elongation of tape due to tension is aggravated by humidity. It is generally acknowledged that plastic tape may be easily deformed beyond its elastic limits. A fact often overlooked, however, is that momentary deformation short of permanent strain may be one of the most troublesome factors in the control of average and instantaneous tape speed. For example, a tape which might be permanently deformed at 6-lb tension may stretch 1% or 2% momentarily with 3-lb tension and produce this percentage as "wow." This condition may also aggravate capstan control problems which will be described later. This factor is the proximate cause of most nonperiodic flutter in tape transport systems.

Tape tensions measured by ordinary means are *average* tensions. *Peak* condi-

tions may vary from this average by a factor of 4:1 or 5:1 on a well-designed machine under dynamic operating conditions. This condition, which we know to exist, creates the basic requirement of any tape drive: that the desired driving force must exceed the total friction in either direction by a factor of at least five, and preferably more. The corollary to this is that the maximum tension expected must never exceed that amount which will produce elongation when expressed directly as a percentage and designated "flutter." These forces may be caused by drag, take-up tension, edge-guide scraping, bearing friction, rubber creepage, vibration and other transient and periodic conditions. The minimum tape tension is a factor of minimum inertia levels and satisfactory tape winding for storage and handling.

Good practice would seem to indicate that the drag and take-up tensions should each equal a safe minimum for tape handling and the capstan drive should pull five times the maximum take-up tension. This procedure puts each tension at its minimum safe value. Particular care must be taken, of course, to prevent any uneven tensions, vibrations, or the rubbing of the edges of the tape on surfaces near the heads and capstan. If care is taken with the handling and storage of plastic tape and if machine tensions and design are reasonable, a satisfactory time-control condition may be obtained to a limit of less than 0.5 sec in 1200 ft of tape.

Capstan Drive

Capstan drive is used almost universally on magnetic tape recorders. This is due, in the main, to the ease of obtaining a constant single-surface speed (as in turntables) with the added advantage of greater energy storage due to higher speeds. Most recorders now available have capstans which, in themselves, can be manufactured to produce less than one tenth of one per cent "wow" or "flutter"; and which can, with synchronous motor drives, reproduce time to satisfactory tolerances for most purposes. At this point, however, most designs begin to experience difficulty. The problem is to couple the tape surface motion to the capstan surface in reference to a transducer spaced some distance from the point of capstan contact.

Two general methods have been used; i.e., the friction surface and the pressure roller. The friction surface suffers from the necessity that the tape tensions must remain constant and of a certain minimum dynamic value, or the tape will not be driven at a given instant. These tensions, when adequate, become sufficient to cause the various phenomena previously described and/or overdrive the capstan so as to cause slippage. The pressure-roller method is in more general use today. This method, however, suffers from certain pitfalls. The rubber surface, which is generally used, is under considerable pressure at the capstan against a small diameter. The surface speed of the rubber, therefore, changes sharply as it passes the capstan. If this rubber is substantially wider than the tape, the rubber surface will drive the tape and is driven by the capstan. Under this condition the creepage of the rubber under compression and motion influences the tape speed directly. As the diameter of the capstan and the durometer of the rubber are increased, this effect is decreased. At the same time, the driving friction between tape, capstan and rubber is materially decreased, increasing the likelihood of slippage. Under either extreme condition (and to a lesser extent between the extremes), the tensions from both the supply and take-up directions will influence the effect of creepage.

When the pressure roller is not wider than the tape, the tape is controlled by the capstan surface and the only slippage factor is relative to tensions and not to creepage. The requirements of tape guiding generally make this method difficult to achieve due to tendencies for

the tape to walk out of the capstan. Also, the increased friction of bearings under greater side-loading pressures may often become a serious factor. In general, the use of as hard a rubber as feasible against as large a capstan as possible with good antifriction bearings on both members will produce the most satisfactory results. These results are then limited by the control of tape tensions.

Tape Supply

The total system drag friction as viewed from the capstan must be as uniform as possible. Since the total must also be a fairly small quantity, the individual sources must be closely controlled. The loading effects of various amounts of tape on various sizes of reels must be minimized. The changes in tape path throughout a reel must not produce changes in tape-guiding friction. Particular care must be taken to insure that the edge guides do not function by brute force to control the tape path, since the pressure of the guides on the slit edges can greatly increase transient tensions and can buckle the tape away from the heads requiring excessive pressure-pad tensions. The dynamic effects of the motion of both tape and reels must be damped to prevent periodic variations in tape tensions. Above, all, the axioms of tape tension ratios must be observed.

Pressure Pads—Pro and Con

Two methods have been in general use to maintain coupling between the tape and the recording or reproducing heads. On professional machines using only plastic tape at high speeds, the combination of supply tension and of the elastic moment of inertia of the tape have generally been adequate to give satisfactory results. As tape speeds are decreased, this is not generally true. At 3.75 and 7.5 in/sec the required longitudinal tensions on the tape to provide adequate coupling exceeds the safe tensions on either paper or plastic tapes, if flutter is considered. On such machines the high-frequency response can be greatly improved by the addition of light pressure pads at the gaps. The only deterrent to this procedure is the increase of head wear and, to some extent, of maintenance. For most applications the improvement in performance is worth the inconvenience.

When paper tape is used, pressure pads become almost mandatory due to the surface irregularities of paper tape. A simple rule of thumb to consider when not using pressure pads is that the useful tension at the gap is equal to the system drag tension times the sine of the angle of incidence at which the tape approaches the head, less the tape stiffness over extremely short lengths.

Take-up Design

Take-up systems may be divided generally into two categories: the constant tape tension and the constant clutch-torque systems. Obviously, constant tape tension is more desirable from a theoretical point of view. On general-purpose recorders the choice is largely economic. If a common motor is used to supply power for a capstan and take-up, it is necessary to use a constant torque clutch in order to equalize the motor load and allow constant motor speed. This is because the power input to a clutch is the product of the speed of the driving member and the torque transmitted to the driven. If the tape tension is held constant, the driving torque required varies 4:1 on a 7-in. tape reel. If the torque is held constant, the tape tension will vary to the same degree.

On professional-quality recorders the goal becomes constant tape tension with means of supplying power from a separate source. The methods used have varied from gravity-operated clutches, in which the weight of the tape controls the tension, to the design of special torque motors whose stalled rotor and slow-speed torque curves are complementary to the changes in tape-reel diameters and weights.

An Integrated Design

If the most desirable features for tape transport and speed control are combined, the result might well resemble the following description.

The supply tension for the tape is provided by a gravity-operated clutch of very light weight and a felt damping pad ahead of the recording head, plus a light pressure pad at the head gap. The total of this tension is maintained at between 1 and 3 oz throughout the reel.

The take-up tension is supplied by a gravity-operated clutch pulling the tape directly from the capstan at from 1 to 3 oz of tension. A separate motor provides power for take-up, transmitting the power to the clutch at a speed not exceeding twice the maximum reel speed at the hub.

The capstan is large in diameter (perhaps over $1\frac{1}{2}$ in.). It is run on precision ball bearings with a ball thrust. The bearings are selected for both dimension and shock-excited noise. A synchronous motor drives the capstan through an idler or multiple-belt drive. The pressure roller is also large in diameter. It has a thick tire of hard synthetic rubber. It is approximately three times the width of the tape. The use of ball bearings is indicated here also. The path wraps the capstan at least 90° between the heads and the pressure roller. Tension on the pressure roller is to be adequate to create an average pulling power for the tape of between $1\frac{1}{2}$ and 2 lb. At this tension the rubber should not compress more than a few thousandths of an inch.

If such a design follows good engineering practice, it may be predicted that the long-term timing from the beginning to the end of a reel of tape will be maintained within less than a half-second time deviation from the nominal, without the use of special synchronizing means. Actually one such device with several tape channels produces repeated timing of all channels within approximately $\frac{1}{8}$ in. in 1200 ft on paper tape. This is equivalent to $\frac{1}{60}$ sec at 7.5 in./sec or an overall tolerance of nine millionths of one per cent. Tape measured on this machine by the elapsed-time method is now a standard of timing for one of the national networks to allow equipment comparison between stations.

When the flywheel or capstan itself is stable (neglecting tape coupling), the short-term flutter and wow should be dependably less than 0.15% rms, or 0.25% peak. As reference, it might be well to point out that this degree of stability is often obtained by manufacturers of competitively priced home recorders, up to the capstan surface. The poorer overall performance is generally traceable to the tape coupling and tension problems discussed above.

A recorder having these characteristics is suitable for most synchronous purposes where and when an absolute phase lock or absolute cue-in control is not necessary. In general, no difficulty should be experienced in using such tape for original preparation of movie sound tracks. With some of the editing procedures now in use, even plastic tape would be feasible. On paper tape, results could be better than one frame error in fifteen minutes. Admittedly, the pure mechanical approach to tape speed control is limited to applications where half-second tolerances are generally satisfactory. It is felt, however, that the investigation of basic principles has uncovered the possibility that many applications, hitherto seeming impractical, may be solved without the expense of synchronous tape equipment.

Acknowledgment

The author would like to express his appreciation for the cooperation and encouragement over an extended period of time of the following people and organizations: L. S. Toogood, L. S. Toogood Recording Co.; R. T. Van Niman; Minnesota Mining and Mfg. Company; and National Standard Co.

Discussion

Anon: The flutter at the capstan was of the order of 0.05%, as differentiated from the flutter at the head. I am wondering what measuring technique was used to determine the wow at the capstan?

Mr. Montgomery: Various means have been used, such as stroboscopic observation of check points on the surface of the flywheel, means of building up systems which have practically no tension or inertia and achieving low wow and flutter measurements to that degree, using capstan drives to pull the tape. Those measurements, by the way, were made on a peak-to-peak basis, when related to actual measurements using tape, rather than on an rms basis.

Dr. Kellogg: I remember a toy we played with in my youth, which consisted of a tin can and a string. You punched a hole in the bottom of the can, and threaded through it a piece of rather stiff string with a knot on the end, then rubbed the string with beeswax and rosin. When you pulled the string, you made a raucous noise, due to the intermittent grip of the fingers on the string. Perhaps a similar thing happens in tape machines, due to the friction of the tape on the magnetic head. Do you know of any indication that such a thing happens? It has been rather difficult to account for the amount of high-frequency flutter.

Mr. Montgomery: Any surface that the tape touches is bound to influence, to some degree, the driving friction of the tape. Since the tape is an elastic medium, if these tensions become at all appreciable, they are translated to the motion of the tape due to its elasticity. That has been a very serious problem with a great number of recorders and, for that reason, the manufacturers have tended to decrease the average running tensions of the tape. Pressure pads can produce exactly the same type of problem and for that reason the tensions and the materials used in the design of pressure pads have to be considered in the light of the longitudinal pressures that they exert when the tape is in motion.

Dr. Frayne: Concerning Dr. Kellogg's question, we have had opportunity over the past several years at Western Electric to measure flutter on a variety of tape machines. We find that most of them, when in good operating condition, have very good low-end flutter or wow. However, on a flutter-measuring set which is capable of measuring side bands up to 200 cycles, we often get rather abnormal values of flutter; in fact, as high as one quarter of one per cent. If you employ a flutter set capable of measuring side bands up to only 50 cycles, you omit the great bulk of the flutter frequencies.

Mr. Montgomery: I might add that some work I was engaged in a while back shows that there was another factor that is quite often indicated as flutter, and which perhaps is indistinguishable from it in the effect on motion analysis. The effect magnetically perhaps may be described as incremental-time (phase) products due to d-c electrical and magnetic components, such as microscopic discontinuities in tape coatings and bias-audio composites, as instantaneous values. To these must be added the side bands produced by *any* frequency modulation present. I don't know how to separate it from flutter in terms of measurement. I wish I did. It is that which we are prone to call modulation noise, which appears as side bands in that same range, quite often within a 200-cycle range of the fundamental and which produced, on most of your flutter-measuring devices, instantaneous changes in phase and in wavefront. Wavefront can confuse the flutter-measuring device so that you don't know which one you have.

Dr. Frayne: The effect on the ear, I think, is the same.

Television Studio Lighting Committee Report

By RICHARD BLOUNT, *Committee Chairman*

Over a period of years the motion picture industry has developed lighting techniques which suit their modes of operation and, similarly, the techniques of the commercial still photographer have evolved to meet his requirements. It is not unreasonable therefore that the television industry, having borrowed some techniques from both groups, has gone on to develop additional methods to meet its peculiar needs.

In order to facilitate this development the Society has formed this Committee, composed of engineering personnel from various television stations, people engaged in motion picture activities, and representatives of the lighting industry. The Committee's members are:

H. R. Bell, Mole-Richardson Co.
A. H. Brolly, Television Associates
D. D. Cavelli, Signal Corps Photographic Center
H. M. Gurin, National Broadcasting Co.
H. A. Kliegl, Kliegl Bros. Universal Electric Stage Lighting Co., Inc.
Ted Lawrence, Columbia Broadcasting Co. (Alternate)
R. W. Morris, American Broadcasting Co.
R. S. O'Brien, Columbia Broadcasting Co.
Adrian TerLouw, Eastman Kodak Co.
M. Waring, Allen B. DuMont Laboratories
R. L. Zahour, Westinghouse Electric Corp.

Presented on May 3, 1951, at the Society's Convention in New York, by Richard Blount, General Electric Co., Nela Park, Cleveland 12, Ohio.

In order to facilitate the investigation of lighting problems common to television stations, the membership has been divided into three groups. A Lighting Facilities Subcommittee including Mr. Brolly and Mr. Morris under the guidance of Mr. Kliegl are investigating:

1. The problems involved in rigging lighting equipment.
2. The power required.
3. The methods of controlling and distributing power throughout the studio.

In addition, this subcommittee plans to study the problems of electrical and lighting maintenance.

This group works closely with a second subcommittee, that on Lighting Techniques, which was until recently under the direction of Mr. O'Brien. Mr. Gurin has agreed to take on the chairmanship of this group because Mr. O'Brien is now spending most of his time in Los Angeles. Messrs. Lawrence and Cavelli complete the group. They are engaged in a study of current lighting practice as applied to theaters, where staging techniques are determined to a large extent by the physical arrangements, to studios where a circus may follow a dramatic show, and to small fixed areas such as daily newscasts, culinary exhibitions, and childrens' programs. While each area has some problems in common, each one must be handled separately if the maximum

effect is to be obtained from the program. In addition this group has been asked to investigate special lighting effects that can be used to enhance the program. Some effects to be studied are background projection, the use of follow spots, and pseudo sunlighting.

A third very important group is engaged in the difficult activity of establishing a basic terminology. This group, including Messrs. Waring and TerLouw under Mr. Zahour's direction, has been very active in its efforts to establish names for various lighting techniques. This work is very necessary because even among the committee differences frequently arise over the meaning of various lighting terms. To date the committee has agreed to a division of lighting into three forms:

1. Base lighting,
2. Accent lighting, and
3. Effects lighting.

Tentatively "base light" has been defined as uniform illumination required on a scene to produce a television image having satisfactory resolution, tonal gradation and signal-to-noise ratio at the point of origin. "Accent lighting" has tentatively been defined as a directional illumination normally added to base lighting to improve the pictorial quality of the television image. No agreement has been reached on even a tentative definition of "effects lighting."

The subcommittee is also investigating technique of light measurement. Realizing that incident foot-candle measurements at times provide insufficient data, they are determining whether brightness measurements may also be used to advantage.

The committee has been meeting at three-month intervals. Our membership is at present predominantly from the East and perhaps should be broadened. Mr. Bell is our sole representative on the West Coast and considering the television activities there other people may wish to contribute to this group. Their participation will be welcomed.

Proposed American Standards

On the following pages appear three Proposed American Standards pertaining to magnetic recording. They cover the direction of film travel, type of base, speed, dimension and positions of magnetic sound tracks on 35-mm, 17½-mm, 16-mm and 8-mm motion picture films with standard perforations.

The proposals are the result of the work of the Sound Committee's Subcommittee on Magnetic Recording, under the chairmanship of G. L. Dimmick. The subcommittee has been active since October 1948, widely investigating the subject through meetings and correspondence among equipment manufacturers, studio sound departments and users of magnetic film.

The Sound Committee and the Standards Committee of the Society have approved preliminary publication of the proposals in the Journal for a ninety-day trial period. If, at the end of that time, no adverse criticism has been received, they will be processed as American Standards.

In the case of the proposals for 35-mm and 17½-mm film, one of the considerations affecting track location is the desirability of reproducing films of both widths on studio editing equipment in particular, and, consequently, the track location on 17½-mm film was made the same as the No. 1 track on 35-mm film, which is the track used when only one recording is made on 35-mm magnetic film. Careful cross-talk and scanning tests have shown the feasibility of recording three tracks on 35-mm film when it is desired to record dialogue, music and sound effects separately and simultaneously, for example, for selective later use and resulting economy of film.

The major equipment manufacturers are supplying equipment meeting these specifications which has proved satisfactory in motion picture studio operations. It should be noted that the 35-mm and 17½-mm proposed standards are for original recording and re-recording and do not apply to release film.

The 16-mm proposal applies only to film having both picture and sound. Later committee work will cover 16-mm sound film with full-width magnetic coating. It should be noted that the photographic emulsion for picture is in the standard position for 16-mm films, and the magnetic coating is on the base side along the unperforated edge. The point of sound translation is also specified as 26 frames which is the same distance and in the same direction from the corresponding picture as is the point of translation for photographic sound track. At least one projector manufacturer is presently considering manufacturing projectors to this proposed standard and others are expected soon.

The proposal for 8-mm film applies to film having both picture and sound. The magnetic coating is along the edge on the base side of the film outside the sprocket holes. The 24-frame speed is recommended for the more serious amateur and for use on professional sound films reduced from 35- or 16-mm material. The 18-frame speed has been selected to replace the former 16-frame standard because of the added improvement in sound quality and the somewhat smoother action in picture material. Several experimental projectors have been built to support the practicability of the proposed standard.

Subcommittee on Magnetic Recording
G. L. Dimmick, *Chairman*
Harold Bauman
H. N. Fairbanks
J. G. Frayne
Robert Herr
G. P. Mann
M. G. Townsley
D. R. White

Proposed American Standard

Dimensions for Magnetic Sound Tracks on 35-Mm and 17½-Mm Motion Picture Film

(First Draft)

PH22.86

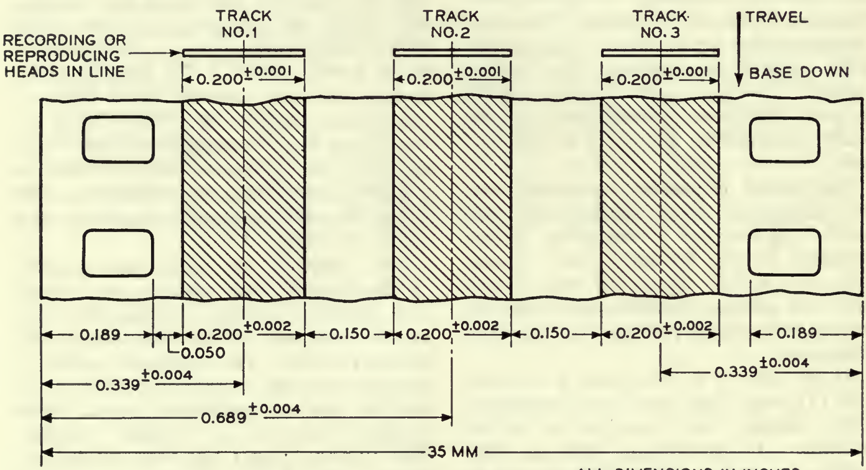
Note 1. This practice pertains to magnetic saund records, bath single and multiple tracks, on 35-mm perforated film, and single tracks an 17½-mm perfarated film.

Note 2. The film base shall be of the law-shrinkage safety type.

Note 3. With the directian af travel as shawn in the drawing, the magnetic material is coated on the upper side af the film base.

Note 4. The magnetic coating is normally applied from edge ta edge.

Note 5. Track dimensions and pasitians are given in inches. All dimensians are given relative ta unshrunk film.



Note 6. Cutting and perfarating dimensians and talerances are identical to those given in Standard Z22.36, "Cutting and Perfarating Dimensions far 35-Mm Motion Picture Positive Raw Stock."

Note 7. Track #1 is the preferred pasitian for 35-mm single track recarding, and is the standard position for 17½-mm recording.

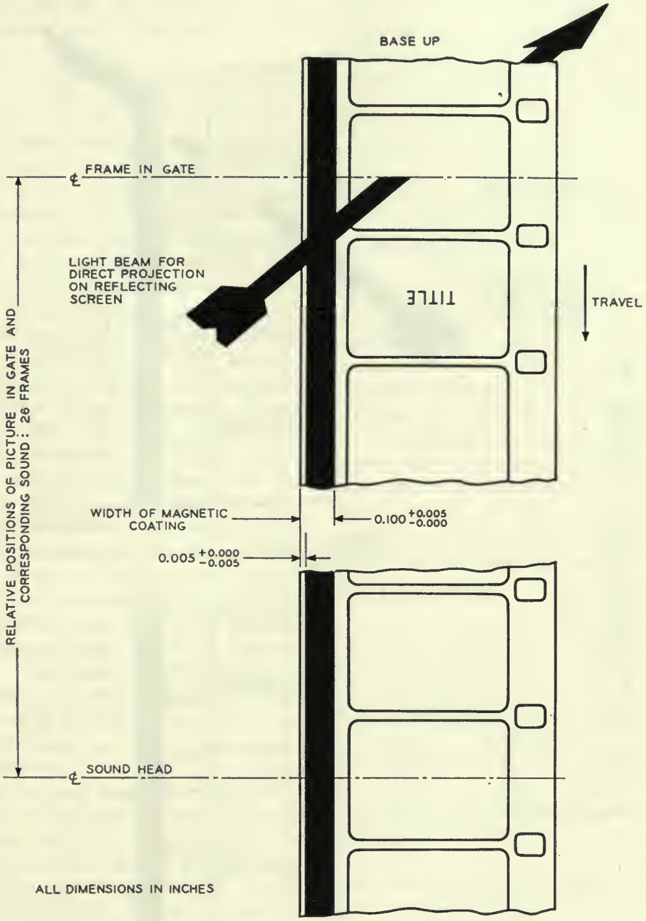
Note 8. Recording and reproducing speed shall be 24 frames per second (Standard Z22.2). This is exactly 96 perforatians per secand and appraximately 18 inches per secand.

NOT APPROVED

Proposed American Standard

Dimensions for Magnetic Sound Track on 16-Mm Motion Picture Film

PH22.87

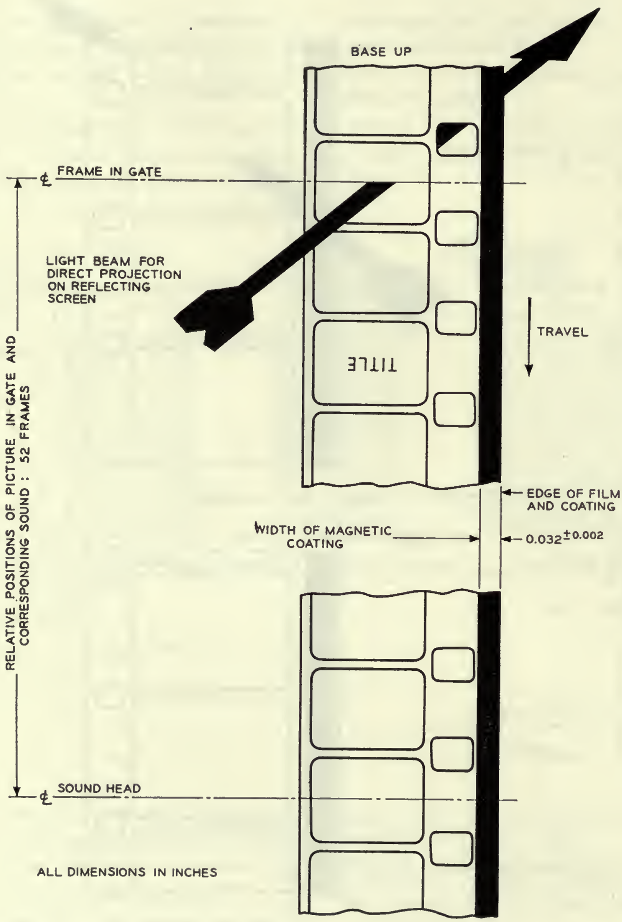


Note 1. The magnetic coating in the above drawing is on the side of the film toward the lamp on a projector arranged for direct projection on a reflection-type screen.

Note 2. Projection Speed — 24 frames per second.

NOT APPROVED

Proposed American Standard Dimensions for Magnetic Sound Track on 8-Mm Motion Picture Film	PH22.88



Note 1. The magnetic coating in the above drawing is on the side of the film toward the lamp on a projector arranged for direct projection on a reflection-type screen.

Note 2. Projection Speeds — 24 frames per second for professional use; 18 frames per second for amateur use.

NOT APPROVED

Board of Governors

The third meeting of the Board of Governors in 1951 was held in New York on July 19. Half-year reports were presented on the state of the Society's finances, on recent membership promotion activities, on publications and on the work of our engineering committees. Also, the Board approved the recommendations of the Nominating and the several award committees.

FINANCIAL The financial aspects of all Society operations over the first six months and the resulting cash position were reported upon by F. E. Cahill, Treasurer, who presented his own report, and, in the absence of R. B. Austrian, also presented the Financial Report.

With the exception of two membership activities, business operations for the first six months of 1951 were about even with the first half of the annual budget adopted in January and well ahead of last year. If the present trend continues, and presumably it will, this should be the best financial year in Society history. But the Board was in agreement that even though the monthly and quarterly operating statements show an attractive picture at the moment, the officers and Headquarters staff members responsible for budgets and financial plans should not relax their attention. They must not assume that "business as usual" represented by last year's or this year's financial reports is an automatic and perpetual condition. With the Society now 35 years old and in every respect healthy enough to continue for another long lap, it would be wise to base plans for the future on a period somewhat longer than just "next year."

A program of long range financing will be prepared for consideration by the Board at its October meeting. Along with the obvious provisions for sustained high level income over a period of several years, there should be plans for continued expansion of the work of engineering committees, the *Journal* and other services to the members and to the industries that employ them.

MEMBERSHIP Each year the Society gains new members but for some time the number of applicants accepted over a 12-month period has very nearly been offset by the number of current members who are delinquent in payment of their dues. Although the net figure, that is, the total of all members in all grades, has always been higher at the end than at the beginning of each calendar year, the growth rate from year to year has been disappointing. To partly remedy the situation the Board six months ago authorized employment of a full time Membership Secretary. Mrs. Beatrice Conlon of the staff began work in that capacity in March and a report of her efforts over the 4-month period was presented. Guests who had attended the 69th Convention were sent membership invitations and out of 25 replies received by July first, 16 applications were approved. Letters addressed to those current members who had not sent in their dues for 1951 produced a 10% return, or about 40 reinstatements. Other specific efforts accounted for a reasonable share of the 334 new members who joined before July 1. The Board called for increased effort on the part of all members of the Membership and Subscription Committee and urged that the major share of this effort be directed toward the up and coming young engineers who could derive real benefit from the *Journal* and other Society activities. They would also doubtless continue as members for a long time to come, if the Society is actually serving its fundamental purpose.

PUBLICATIONS Editorial Vice Presidents C. R. Keith and J. G. Frayne, the Editor Vic Allen, and Arthur Downes, Chairman of the Board of Editors, have devoted a great deal of effort to tightening the editorial policy of the *Journal*. They aimed at reducing delays between presentation and publication of technical articles, raising the average levels of both editorial and technical quality of papers submitted for the *Journal* so there would be a wider selection of suitable material from which to assemble any given issue and to increase the amount of information published. In addition, they wanted more pages in the "back of the book," this section that reports on the Society and its internal workings.

In a written report submitted by John Frayne, who was not able to attend, ample evidence of progress was presented. The change to two column format authorized last October had been made on schedule, beginning with the issue for January. New

paper and ink were also adopted. These changes were intended to give more words per page, improve appearance and readability, and at the same time permit somewhat greater flexibility in make-up of the "back of the book" and in articles with numerous illustrations. Twenty-five per cent more material was contained in the first six issues for 1951 than appeared in the first six last year and 60 per cent more than in the same period in 1947.

By working closely with the Mack Printing Company and by applying added personal effort, Vic Allen was able to make the *Journal* a larger, more professional magazine. In recent months, however, the addition of such items as the High-Speed Photography Bibliography, the 5-Year Index, the new style volume title page and index that appeared in June plus a series of technical papers that required more detailed care to publish, required so much extra attention that publication dates began to lag. Extra manpower seemed to be the only solution, so on Dr. Frayne's recommendation the Board authorized Vic Allen to employ an Assistant Editor, increasing the editorial staff to three.

The Papers Committee, for which the Editorial Vice-President is responsible, has been working seriously on plans for the 70th Convention. Fred Albin, Vice-Chairman, and Ed Seeley, Chairman, have switched the program into high gear.

Development of a high quality public address and discussion recording system for use at conventions had been assigned to Dr. Frayne. He appointed a committee under the chairmanship of Harry Braun to work out the detailed design. The Committee's recommendations were approved, so that work can be started at once.

ENGINEERING Fred T. Bowditch, Engineering Vice-President, reviewed the system of Stenotype recording and transcription used in the preparation of minutes of many of the engineering committees' meetings held during the 69th Convention. He criticized the use of "outside" help on this job because the results did not justify the expense. For that reason future meetings of engineering committees that Hank Kogel, Staff Engineer, cannot attend will be reported by a recording secretary, whom the chairman will appoint on the spot.

One of the methods of measuring lens transmission that the Optics Committee had considered suitable for a proposed standard is the subject of a U. S. Patent assigned to the Radio Corporation of America. Mr. Bowditch reported that since the patent could have been a serious obstacle to general use of the method it was fortunate that the Radio Corporation of America had seen fit to offer a paid up license to anyone interested for the sum of $10.00. Appreciation had been formally expressed in the June *Journal*.

Most important engineering item on the Agenda was concerned with the position which the Society would assume in connection with the forthcoming hearings on Theater Television of the Federal Communications Commission.

After duly considering the combined views of the Theater Television Committee and its Subcommittee on Distribution Facilities, under G. L. Beers and Pierre Mertz, Chairmen, the Board agreed that the Society should act on the recommendations and not make an appearance. Steps taken to notify FCC, industry trade groups that took part in this work and the press are reported upon elsewhere in this issue.

CONVENTIONS Although most members who help put on Society Conventions twice each year are concerned with only one at a time, Convention Vice-President Bill Kunzmann is always looking far into the future. Convention hotels are booking large conventions as far as two to three years ahead, so Bill has tied up these dates:

70th Convention, Hollywood Roosevelt, Hollywood, Calif., October 15–19, 1951

71st Convention, Hotel Drake, Chicago, Ill., April 21–25, 1952

72nd Convention, Hotel Statler, Washington, D.C., October 5–10, 1952

73rd Convention, Hotel Statler, Los Angeles, Calif., April 26–30, 1953

74th Convention, Hotel Statler, New York, October 4–9, 1953

The Board of Governors authorized these five reservations and learned that all Committees for the 70th Convention have been appointed and are now hard at work. Details are given elsewhere in this issue.

70th Semiannual Convention

Hollywood Roosevelt Hotel, Hollywood, Calif., October 15–19, 1951

You can bet that the 70th Convention will be up to Bill Kunzmann's usual standards. He has turned in two good ones every twelve months for 35 years and as Convention Vice-President and entrepreneur par excellence he should make the next the best so far.

During June, Bill met twice with President Peter Mole and the Pacific Coast Section Managers to arrange the feature events. He has prepared a list of these items in sequence and as soon as essential details are filled in by his planning team Bill will arrange for Vic Allen to print the advance notice and mail it to all members. The customary hotel reservation card will, of course, be included as will session titles and enough general information about the program to enable members to crystallize their personal plans.

Following the advance notice (by the shortest possible time interval) will be the tentative program, also to be printed by Vic Allen and mailed to all members. For each paper listed the tentative program will show title, author, author's affiliation, and a brief abstract of the paper's contents. Although some changes are inevitably made in the separate items and in their order of presentation after the tentative program is completed and before the final program goes to press, every effort is made to keep these changes to a minimum. The final program will be distributed at the Registration Desk on opening day, Monday, October 15.

PROGRAM *Fred Albin*, American Broadcasting Co., 4151 Prospect Ave., Hollywood, Calif.

As Papers Committee Vice-Chairman for the Hollywood area, Fred is in charge of organizing technical sessions, perhaps including a symposium or two. In making up the Program, he will be able to draw from fifty or sixty separate contributions offered directly by individuals or secured by other members of the Papers Committee. Help with procedure, and in the way of program suggestions, will come from J. G. Frayne, Editorial Vice-President, and E. S. Seeley, Chairman of the Papers Committee. When enough manuscripts have been received to give form to the program schedule, Fred will draft the tentative program. He urges that prospective authors who have not furnished either manuscript or author's form do so at once. Proper blanks are available from any of the Vice-Chairmen whose names are listed on p. 690 of the June *Journal.*

LUNCHEON AND BANQUET

Norwood Simmons, Eastman Kodak Co., 6706 Santa Monica Blvd., Hollywood 38, Calif.

An essential assignment in connection with the Monday luncheon and Wednesday banquet has been given to Norwood. He will schedule the presentation of all annual awards and help select the luncheon speaker. As Peter Mole's aide he will see that the "official" parts of both social events begin and end on time. He will also receive official guests, seat them, and serve as assistant host for each occasion.

LADIES *Mrs. C. R. Daily*, 113 N. Laurel Ave., Los Angeles 36.

As Chairman of the Ladies Committee Mrs. Daily will be official Convention Hostess. She will appoint the Ladies Committee, help with the program of entertainment for those of the fairer sex who attend, and while the Convention is in session she will be their guide and mentor.

MOTION PICTURES

Sid Solow, Consolidated Film Industries, 959 Seward St., Hollywood 38.

Motion Picture short subjects of better than average quality are used to open all technical sessions. Sid will schedule and book all the required films, arrange for delivery to the Hollywood Roosevelt before each session, and for pick-up afterward. In addition (as is customary) he will be superintendent of nonsense and engage the entertainer for the Monday luncheon.

PUBLICITY *Harold Desfor*, RCA Victor Div., Camden, N.J.

Taking a ten-day leave of absence from his regular job, Harold will set up publicity

headquarters just outside the Manager's office in the Hollywood Roosevelt Hotel. Beginning Monday he will prepare one or two daily press releases telling the story of the Convention as it unfolds. Before the doors open, however, he will have examined all manuscripts for newsworthiness and have prepared written abstracts (in layman's language) of the important parts of each paper. Reporters from trade and city papers can then study them all in understandable capsule form.

PRICES *Bill Kunzmann*, National Carbon Division, Box 6087, Cleveland 1, Ohio

Registration for the week	$ 5.00
Registration for a single day	1.00
Ladies Registration (week)	2.00
Luncheon (tax and tip included)	4.00
Banquet* (tax, tip and cocktails included)	11.00

* *Bill Kunzmann said to remind everybody that the banquet is informal.*

Theater Television and the FCC

THE ENTIRE FIELD of theater television reached and passed an important milestone in the month of July 1951. After pleading the cause of theater television in many places and with great enthusiasm over the better part of a decade, the Society is no longer the only vocal public proponent. Theater circuits, exhibitors' trade organizations, manufacturers and the common carriers have joined the parade.

Equipment is being made, sold, installed and used on a commercial scale and the companies concerned with all aspects of equipment, operation and programming, as well as their trade organizations are beginning to move in a single general direction. Before long this link of communications between motion picture exhibition and television will be an integral part of the nation's entertainment industry.

As a consequence of this *imminent maturity*, our Theater Television Committee and its Subcommittee on Distribution Facilities believe that the new industry is well able to solve its own *commercial problems*. They have so advised the Board of Governors, recommending that the Society make no further appearance before the Federal Communications Commission in this connection, on its own initiative. Forthcoming hearings of the FCC described in Docket No. 9552 fall into the "commercial problems" category, because in addition to considering certain technical matters, the hearings will produce specific requests for allocation of sections of the radio frequency spectrum to the use of theater television. And they will also produce requests for the assignment of particular channels within those "theater television bands," to particular commercial interests. Using these two factors as a basis for its decision, the Board of Governors at its meeting in New York on July 19 ruled that the SMPTE would not appear at the forthcoming hearings.

FCC

Immediately following the Board Meeting, President Mole addressed the following letter to Mr. T. J. Slowie, Secretary of the Commission:

"The Society of Motion Picture and Television Engineers has given consideration to having its representatives appear at the hearings of the Federal Communications Commission beginning the first week in December and relating to channel assignments and related matters for theater television. The Society has for many years been active in studies of theater television methods, equipment and engineering aspects.

"Its primary functions in the developmental stages of theater television include the following: to coordinate the varied approaches which individuals and companies in the motion picture industry have taken toward the problems of creating the means of theater television; to establish desirable performance objectives practical of attainment at each stage of the art, and economic in the sense that equipment and facilities must be both manufacturable and operable; to arrange for the free exchange of information on video bandwidth, number of lines and suitable signal-to-noise ratios. These results have been accomplished through the Society's engineering committees.

"The consequence of this SMPTE coordination will doubtless be constructively evident in the statements soon to be filed with the Commission by commercial interests who propose to establish and to operate portions of a national theater television service. To further the development of such a service the Society is ready to serve the Commission as well as the motion picture industry through its study of particular technical questions.

"The Board of Governors of the Society believes that the Society's mission in the present preliminary stage of theater television development has been accomplished, citing as evidence the present broad interest of the industry as well as the constructive measures which the industry now proposes. Since the Society is a technical organization (and not a commercial institution), and since it will, of course, not propose to operate any portion of the theater television service, it does not propose to apply for the use of a band of frequencies in the radio spectrum, and for that reason does not propose to file an appearance nor otherwise participate in the forthcoming hearings. Further, the Society is convinced that the matters under consideration at these hearings can be adequately and informatively handled by the qualified engineering representatives of motion picture organizations there appearing.

"The Society has historically taken a constructive, cooperative and active position with respect to theater television. It is a pleasure to report that its Board of Governors continues its full interest in that field and has today authorized the following statement of its position with respect to the forthcoming hearings in the matter of Allocation of Frequencies and the Promulgation of Rules and Regulations for a theater television service.

1. The SMPTE, as a scientific and engineering society, is concerned primarily with technical matters. It is not concerned with commercial or industrial matters as such, and does not undertake to represent or speak for the motion picture industry or its parts.

2. The field of theater television has now reached a stage of technical and commercial development such that individual organizations appear qualified to express their viewpoints. Accordingly, the participation of the SMPTE in regulatory hearings no longer appears necessary.

3. However, upon the request of the FCC the SMPTE will assign to its technical committees the task of studying specific technical questions and will thereafter present to the Commission the technical opinions and data they can produce.

"The Society particularly directs the attention of the Commission to its willing offer of further technical service whenever requested."

Industry

Since other industry groups had of recent years been either taking an active part in the Society's committee deliberations or following closely, developments within its committees, it was particularly important that they know where the Society stands at the present time. To keep them informed, President Mole wrote on the morning of July 20 to the Presidents or senior staff members of these eight organizations:

Motion Picture Association
Theatre Owners of America
Society of Independent Motion Picture Producers
Allied States Association of Motion Picture Exhibitors
Motion Picture Research Council
Metropolitan Motion Picture Theatre Owners Association
Independent Theatre Owners Association
National Exhibitors Theater Television Committee

Enclosing a copy of the statement to the FCC, the letters read in part:

"We believe the cooperative spirit that has characterized the industry-wide interest in theater television over the last few years has formed a firm basis for an effective theater television service, and we earnestly hope it will continue. The present outlook is most encouraging.

"In the same constructive spirit I have been asked by our Theater Television Committee and its Subcommittee on Distribution Facilities to extend the following invitation to all industry groups who have taken part in our work or otherwise shown a serious interest. If you find it convenient please pass this invitation along to the members of the [your organization] as

evidence that the SMPTE has no intention of stepping aside at this juncture.

"[Your organization] is invited to call upon the Society of Motion Picture and Television Engineers at any time for assistance in the study of specific technical matters. The results of such studies would, as is customary, be presented for free use of the industry at large."

Continued Interest

Mr. Mole and the Board felt it was important to avoid giving the impression that the Society was stepping aside now, after so many years of active interest in promoting early technical progress in this comparatively new field. The present move implies rather that the Theater Television Committee is now ready to concentrate on technical details and, like all other engineering committees within the Society, is at the service of all segments of the industry.

For a review of past work in this connection, look up the following:

1. "Statement on theater television," Theater Television Committee, D. E. Hyndman, Chairman, *Jour. SMPE*, vol. 53, pp. 354–362, Oct. 1949.
2. "FCC allocation of frequencies for theater television," *Jour. SMPE*, vol. 53, pp. 351–353, Oct. 1949.
3. "Theater television," Theater Television Committee, D. E. Hyndman, Chairman, *Jour. SMPE*, vol. 52, pp. 243–272, Mar. 1949.
4. "Statement of SMPE on revised frequency allocations," Paul J. Larsen, *Jour. SMPE*, vol. 48, pp. 183–202, Mar. 1947.
5. "Report of the Committee on Television Projection Practice," P. J. Larsen, Chairman, *Jour. SMPE*, vol. 47, pp. 118–119, July 1946.
6. "Frequency allocations for theater television," *Jour. SMPE*, vol. 45, pp. 16–19, July 1945.
7. "Statements of the Society of Motion Picture Engineers on allocation of frequencies in the radio spectrum for theater television service as presented before the Federal Communications Commission," *Jour. SMPE*, vol. 44, Feb. and April. 1945.

Letters to the Editor

Re: A Study of Current Misconceptions in the Optical Theory of Rotating Prisms for High-Speed Cameras

Summary: The analysis of the rotating prism, as published by J. H. Waddell in this JOURNAL, *is wholly invalidated by an initial mathematical error. The correct calculation shows increasing speed of image displacement for increasing angle of rotation—a result directly opposite to that obtained by Waddell. Moreover, the advertised statement that "high index low dispersion glass" improves the resolution is without real foundation, as the influence of the value of the refractive index on the prismatic aberrations is practically insignificant.*

A DESCRIPTION of the image formation by rotating prisms was given by J. H. Waddell,[1] with particular attention to the change in the speed of image displacement with increasing angle of rotation.

Unfortunately, a substantial mathematical error crept into the basic formula upon which Waddell's investigation was built up. His formula (5), which should be the differential quotient of equation (4), is essentially incorrect. The mistake in differentiation led to the conspicuously false Fig. 2 in Waddell's paper, showing a curve turning downward to zero speed for increasing angle. In reality, the correct curve turns upward with increasing angle.

The writer has previously given a quantitative survey of the optical aberrations in question.[2] The image produced by the camera lens is continuously displaced by the rotating prism during the exposure. The displacement is

$$D\,\frac{n-1}{n}\left[x + \left(\frac{n+1}{2n^2} - \frac{1}{6}\right)x^3\right] \quad (1)$$

in which D is the thickness of the polygonal prism, n is the refractive index, and x is the angle of rotation in radians (i.e., the angle between the optical axis and the normal to the prism face).

The angle x being proportional to the time, the speed of the image displacement is proportional to the differential quotient of formula (1):

$$D\frac{n-1}{n}\left[1+3\left(\frac{n+1}{2n^2}-\frac{1}{6}\right)x^2\right] \quad (2)$$

This shows a fast increase of the image displacement for greater values of the angle x. Against this result, Waddell's Fig. 2 shows a decrease to zero and even to negative speeds with increasing angle, which is obviously wrong.

In Waddell's paper, as well as in other descriptions, particular emphasis is laid on the statement that improved resolution has been achieved by a new prism made of "high index low dispersion glass." However, this cannot be motivated by the slight influence of the refractive index on the nonlinear term in formula (1), as the whole effect of this aberration is practically obliterated by a suitably chosen value for the thickness D of the prism, which fact should be carefully realized. The value of the thickness D is usually chosen so that formula (1) indicates complete image coincidence for three positions of the rotating prism, representing, the beginning, the middle and the end of the exposure time. Thus any possible effect of nonlinearity is deliberately restricted to some intermediate positions of the prism, which means such small numerical values for the residual nonlinearity, that this aberration is practically eliminated, irrespectively of the value of the refractive index. It would be rather meaningless to argue that the coefficient of x^3 in formula (1) has the value $\frac{7}{18}$ for $n = 1.5$, and the smaller value $\frac{5}{24}$ for $n = 2.0$, since the practical effect on the image formation in either case is negligible, if the exact value for the thickness of the prism has been properly chosen.

As far as dispersion is concerned, its effect is proportional to the angle of rotation during the actual exposure in the high-speed camera, but it remains negligible for any rotating prism of low dispersion glass. Thus it remains to find out how other rotational aberrations depend upon the refractive index. In this respect, only prismatic coma and astigmatism have to be considered. The numerical value of these aberrations is proportional to $\frac{n+1}{n^2}$, if n is again the refractive index of the prism. Consequently, under otherwise identical conditions, a polygonal prism of high index glass (e.g. $n = 1.8$) would reduce prismatic coma and astigmatism by only 20%, as compared with the case of a prism of low index glass, such as $n = 1.5$. The practical insignificance of such a slight change in the size of aberrations can be illustrated as follows: Let us consider a camera with a rotating prism of high index glass ($n = 1.8$), under the condition of an overall limitation of the angle of incidence to $7\frac{1}{2}°$. Replacing this high index prism by a low index ($n = 1.5$) prism of suitable thickness, the optical aberrations remain exactly the same if the maximum angles of incidence are limited to 7°, i.e., only half a degree below the limits referred to in the allegedly ideal case of a high index glass.

This comparison shows that there is no real meaning in the argument of the "high index low dispersion glass," however esoteric an appeal might emanate from it.

The problem of optical improvement of this type of high-speed cameras is neither so simple nor so limited and hopeless, as suggested by recent literature. As soon as priority is granted to the optical problem, an unexpected progress in the construction of high-speed cameras of the rotating prism type will become possible. The presently prevailing attitude is based on the principle of a preconceived gear-box, which is really a Procrustean bed into which the optics has to be stretched or mutilated. There are surely more drawbacks than advantages in having a gearing between film driving and prism movement. But such a gearing is not an inherent feature of the construction, as the optical solution is compatible with a single rotating unit, serving the double purpose of optically displacing the image and mechanically displacing the film.

March 24, 1951

J. Kudar
601 W. 113th St.
(Apt. 10F)
New York 25, N.Y.

References

1. J. H. Waddell, "Design of rotating prisms for high-speed cameras," *Jour. SMPE*, vol. 53, pp. 496-501, Nov. 1949.
2. J. Kudar, "Optical problems of the image formation in high-speed motion picture cameras," *Jour. SMPE*, vol. 47, pp. 400-403, Nov. 1946.

Errata

J. H. Waddell, "Design of rotating prisms for high-speed cameras, *Jour. SMPE*, vol. 53, pp. 496–501, Nov. 1949.

Page 497: *For*

$$\frac{d(ss')}{dt} = kT\left[\frac{\cos i - 4(n^2 - \sin^2 i)\cos 2i - \sin^2 2i}{4(n^2 - \sin^2 i)}\right] \tag{5}$$

read

$$\frac{d(ss')}{dt} = kT\left[\cos i - \frac{4(n^2 - \sin^2 i)\cos 2i - \sin^2 2i}{4(n^2 - \sin^2 i)}\right]. \tag{5}$$

Page 498: *For* Fig. 2, *substitute* the figure shown on p. 83.

Reply to the Letter Above

In reviewing the Letter to the Editor by Mr. Kudar, in reference to a study of current misconceptions in the optical theory of rotating prisms for high-speed cameras, there are a number of very interesting observations to be made in reference to this critique by Mr. Kudar.

There was, as has been turned over to the Society, a typographical error in Formula 5 in the paper, *Design of Rotating Prisms for High Speed Cameras* by John H. Waddell, and consequently in the calculations that illustrated Fig. 2 positive values are shown rather than negative values as the relative velocity. However, quoting from a letter from one of my former associates, it is to be pointed out that this does not affect the validity of thinking in the design of rotating prisms in the least.

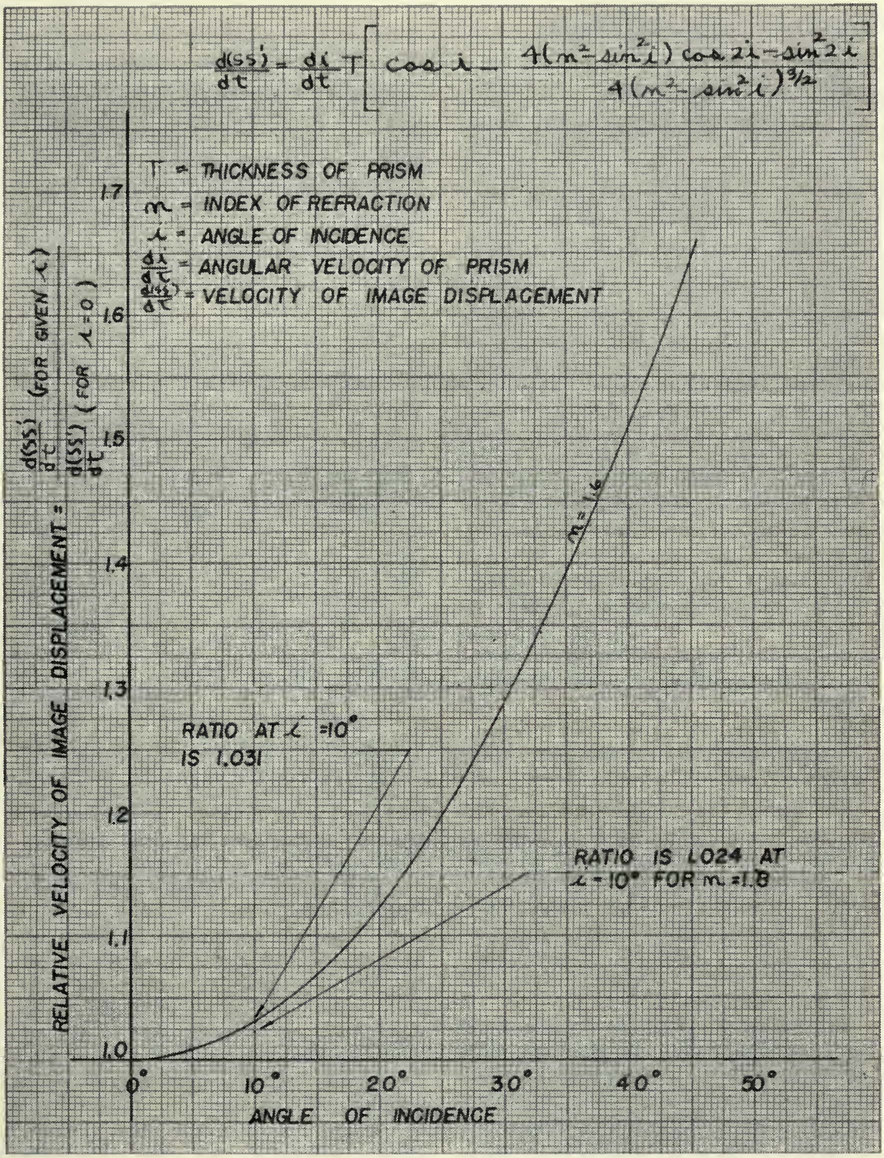
As one recalls from the oral presentation of this paper in the city of Washington at the first High-Speed Photography Symposium, the data to indicate that the high index glass prisms would prove of advantage was illustrated with a number of curves covering the various types of prismatic aberrations and distortions from the Kudar paper which was published in the *Journal* (vol. 47, pp. 400–403, Nov. 1946). In those figures it can be shown conclusively, as was demonstrated, that the optical quality of the image is improved by going to the higher index glass. Furthermore with the new Kodak high index low dispersion glass many improvements have been made practically in the formation of the optical image transmitted through the prism and on to the film plane both by the use of this glass and reducing the angle of incidence through which the exposure was made.

Practical considerations in the design of high-speed cameras indicate that the engineers are more interested in a very short cycle of exposure than such as would be required for continuous projection.

There is considerable stress placed by Mr. Kudar in the selection of the high index glass versus the low index glass. It must be remembered that radius in centrifugal force is reduced through the use of high index glass and any factor which can be made to reduce centrifugal force in very high speed moving mechanisms is to be considered seriously. It is not felt that the approach has been esoteric as Mr. Kudar has emphasized but primarily from a practical design wherein the practical optics do not necessarily meet with the approval of the theoretical man. There has to be a compromise between theory and practice at all times and when one is able to design a camera which produces a picture which is as steady as one taken with an intermittent camera and with resolving power equal to that of the normally fast films of today the compromise in the practical optics has been well satisfied.

As far as the comment about gear trains et cetera, they do not enter into the picture in the least because the tolerances to which cameras are made now are primarily proprietary information and therefore it is not felt that it is wise to discuss tolerances of manufacture of high-speed motion picture cameras in a paper of this type.

It is felt that if one examines pictures taken with the rotating prism cameras of today that they will be very satisfied with the photographic quality obtained. True, the next problems of design, of course, are to produce sprockets and other parts of the moving mechanism which are more ideally suited for both super speed operation wherein the cameras will operate at



four times their present rate of speed or larger image size such as could be obtained on a full frame 35-mm camera both of which are under current development.

June 20, 1951

John H. Waddell
850 Hudson Avenue
Rochester 21, N.Y.

[At press time, a Letter from Dr. Kudar came to the Editor further setting forth Dr. Kudar's ideas on the problem of centrifugal stress and strain in rotating prisms.]

Engineering Activities

ASA Standards for Color

American Standard Methods of Measuring and Specifying Color, Z58.7.1–3, 1951, approved April 13, 1951, have been published by the American Standards Association. They consist of three parts, each one numbered differently so that workers concerned with separate phases may refer to each part separately. This Z58.7 set of standards is a revision of War Standard Z44–1942, taken over for revision by the recently formed ASA committee Z58, Sectional Committee on Standardization of Optics, Francis W. Sears, Chairman, sponsored by the Optical Society of America. The revision was handled by a subcommittee of which David L. MacAdam of the Eastman Kodak Co. served as chairman. The three standards are titled as follows:

Z58.7.1–1951, American Standard Method of Spectrophotometric Measurement for Color;

Z58.7.2–1951, American Standard Method for Determination of Color Specifications;

Z58.7.3–1951, American Standard Alternative Methods for Expressing Color Specifications.

The first standard states the scope, then sets up seven provisions that relate to spectrophotometric measurement of color: 1, wavelength range; 2, bandwidth; 3, stray radiant energy; 4, nominal wavelength; 5, photometric scale; 6, spectral reflectance; 7, spectral transmittance. This is followed by a discussion, with nine numbered paragraphs.

The second standard sets up procedures for computing color specifications from spectrophotometric measurements in terms of the well-known and widely used tristimulus values X, Y and Z which are based on values for the equal-energy spectrum (and the "Standard Observer") adopted in 1931 by the International Commission on Illumination (380–780 mμ). Tables of values I.C.I. Standard Source C (380–770 mμ) are included for use both by the weighted ordinate (10-mμ interval) method and the selected ordinate method of calculation. Trichromatic coordinates (x, y, z) are given for the spectrum (380 to 780 mμ in 5-mμ intervals). The usual ICI (x,y)-chromaticity diagram is presented as the American Standard Chromaticity Diagram. All illuminations other than ICI Standard Source C are referred to as "nonstandard," and while it is pointed out that sometimes it may be important to use other sources in computation, the result "should not, however, be designated American Standard."

The third standard establishes alternative methods for expressing color in terms of dominant wavelength, purity and luminance; and secondly, in terms of Munsell hue, Munsell chroma and Munsell "value," "by interpolation in tables and charts prepared by the Subcommittee on the Spacing of the Munsell Colors of the Colorimetry Committee of the Optical Society of America, 1943." It is noted that these two sets of terms specify quantities that correlate more or less satisfactorily with hue, saturation (chroma) and lightness (value), defined as "features of color sensation and perception," but that the Munsell terms correlate somewhat better than dominant wavelength, purity and luminance for opaque, reflecting materials under usual conditions of observation.

There are many things in these standards that need to be studied. In some respects they are wordy and less clear than Z44–1942 which they are intended to replace. In other respects they are an improvement. The limitation they set, * that to comply with American Standard Methods one must do all colorimetric measurement and specification through spectrophotometry, is so extreme and so impracticable, in the opinion of the reviewer, that it will certainly lead to revisions in the standards if they are to become as useful in American practice as they could be. Omission of

* The standards set this limitation, although the Foreword states that any method may be used for sections 1 and 2 that will provide equivalent results. Specific note is made, however, that "This Foreword is not a part of the American Standard Methods. . . ." Either the note is incorrect, so that the Foreword should be a part of the standard, or only specifications arrived at through spectrophotometry comply with the standard methods.

direct and full reference to the internationally adopted resolutions of the 1931 (and other) meetings of the International Commission on Illumination, as the basis for these American Standards, is an omission that is confusing. American acceptance of so much of the ICI recommendations for colorimetric practice is so very general that it would have clarified the meaning of some of the American Standards provisions if more direct reference were made as to those parts adopted, and those parts omitted, of the ICI recommendations. (A typographical error in the heading of the last section of the third standard should be noted: "Deflecting" is written for Reflecting.)

However, the committee has worked long and hard to reach a point of agreement and of ASA approval and publication. Dr. MacAdam served as chairman of the subcommittee, and he had on the committee many members who served as representatives of ASA member-associations, firms, or cooperating governmental organizations. Among them were: Carl Z. Draves (for the AATCC); I. H. Godlove (for the Ansco division of General Aniline and Film Corp.); S. M. Newhall (for APA); M. Rea Paul (for ASTM); A. J. Werner (alternate for Corning Glass Works); Wm. F. Little (for Electrical Testing Laboratories); Norman F. Barnes (alt. for General Electric Co.); C. L. Crouch (alt. for IES); W. R. Brode (for OSA); Fred E. Altman (for SMPTE); D. B. Judd (for National Bureau of Standards); and E. K. Kaprilian (for Dept. of Army Signal Corps). (Initials have been used for ISCC member-bodies.)

Later it may be useful to publish a critical review of these standards, but at present it seems enough to let all color workers know that we now have available a set of ASA standards for use in measuring and specifying color. Copies of the set of three standards (15 pp.) may be purchased at fifty cents per set direct from the American Standards Association, 70 E. 45th St., New York 17.—D.N. (*Reprinted from I-SCC News Letter No.* 94)

Back Issues of the Journal Available

Three and one-half years of the Journal, July 1947 through December 1950, are available at the job lot price of $25.00 from Mr. Max Prilik, c/o Circle Theater, 82 H Grant Circle, The Bronx 60, N.Y.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were Published in the April *Journal.*

Obituary

Albert L. Raven died on July 11 after a long illness at the age of 75. He was President of the Raven Screen Corp., 124 E. 124th St., New York, which he founded in 1921.

As a young man he had traveled on cruise ships as a photographer for Underwood & Underwood. He also had been employed by the Nicholas Power Co., working with motion picture equipment, before developing and marketing his ideas for motion picture screens. He invented a perforated screen and perfected a "halftone" screen with high reflective powers accomplished with a facing of cotton backed by titanium and rubber to get white color and opaqueness. This screen was used by Eastman Kodak Co. for its *Cavalcade of Color* at the New York World's Fair. In the 1930's the Raven Screen Co. boasted "a screen in every house on Broadway." More recently the company has concentrated on screens and related equipment for homes and institutions. Mr. Raven had been a member of this Society since 1924.

New Members

The following members have been added to the Society's rolls since those published last month. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY.

Honorary (**H**) Fellow (**F**) Active (**M**) Associate (**A**) Student (**S**)

Aerts, Rene, General Sales Manager, The Gevaert Co. of America, Inc., 423 W. 55 St., New York 19, N.Y. (**A**)

Applebaum, Joseph H., Cameraman, Coronet–Industrial Newsreels, Inc. **Mail:** 9 Post Ave., New York 34, N.Y. (**M**)

Bassett, Fred E., Jr., Motion Picture, Sound and Projection Engineer, RCA Service Co., Inc. **Mail:** 1131 Venetia Ave., Coral Gables, Fla. (**M**)

Boyers, John S., Engineer, Magnecord, Inc., 225 W. Ohio St., Chicago 10, Ill. (**A**)

Brown, Freeman H., Director, Photo Laboratory, The University of Wisconsin. **Mail:** 1204 West Johnson St., Madison 6, Wis. (**A**)

Clemson, Stanley L., Sound Engineer, Queensway Studios. **Mail:** Valley Farm Rd., Pickering, Ontario, Canada. (**M**)

Cummings, Wilbur H., Radio and Television Broadcasting, American Broadcasting Co. **Mail:** 427 Cottage Ave., Glen Ellyn, Ill. (**M**)

Downs, Charles W., Jr., Free-lance Assistant Cameraman. **Mail:** 1060 Hunter Ave., Pelham Manor, New York. (**A**)

Dunkelman, Gerald F., Sound Engineer, RCA Service Co., Inc. **Mail:** 194 Oakdale St., Staten Island 12, N.Y. (**A**)

Frank, Emil H., Television Executive. **Mail:** 550 Fifth Ave., New York, N.Y. (**A**)

Harding, H. Theodore, Motion Picture Product Manager, E. I. du Pont de Nemours & Co., Inc., 1450 Nemours Bldg., Wilmington, Del. (**M**)

Indjian, Daniel, University of Southern California. **Mail:** 1470 S. Shenandoah St., Los Angeles 35, Calif. (**S**)

Irvine, William L., Photographer, Corps of Engineers, U.S. Army. **Mail:** 2919 South 8th St., Kansas City 3, Kan. (**M**)

Kaplan, Richard, Dept. of Cinema, University of Southern California, Los Angeles 7, Calif. (**S**)

Koppel, Leo, Works Director, Ship Carbon Co. of Great Britain, Ltd. **Mail:** 51 Mount Pleasant Rd., Chigwell, Essex, England. (**A**)

Lummis, Oscar W., Sound Engineer, RCA Service Co. **Mail:** 3009 Magee Avenue, Philadelphia 24, Pa. (**A**)

Mahon, John C., Jr., Instructor, Motion Picture Photography, University of California at Los Angeles. **Mail:** 6608 Jamieson Ave., Reseda, Calif. (**A**)

Marcus, Joseph, Engineer, Federal Manufacturing and Engineering Corp. **Mail:** 1269 E. 89 St., Brooklyn 36, N.Y. (**M**)

Mathiesen, George H., Television Engineer, KPIX, Inc. **Mail:** 301 Ricardo Rd., Mill Valley, Calif. (**A**)

Meyer, H. J., Factory Representative, West Coast, Wollensak Optical Co. **Mail:** 1260 Lago Vista Dr., Beverly Hills, Calif. (**M**)

Pedersen, Raymond L., University of Hollywood. **Mail:** 930 N. Edgemont St., Los Angeles, Calif. (**S**)

Polito, Eugene E., Free-lance Cinematographer. **Mail:** 1456 N. Ogden Dr., Hollywood 46, Calif. (**M**)

Rella, Fred A., Motion Picture Production Supervisor, New York State Dept. of Commerce, Motion Picture Unit, 40 Howard St., Albany, N.Y. (**M**)

Rogan, Barney B., Electrical Technician & Sound Recordist, Mode-Art Pictures, Inc. **Mail:** R.D. #12, Pittsburgh 29, Pa. (**A**)

Schick, Elliot, Producer-Director, TV Films, President, Nova Productions, Inc. **Mail:** 179 West St., New York 7, N.Y. (**A**)

Sheldon, Irwin R., Design Engineer, Precision Laboratories. **Mail:** 300 Ocean Parkway, Brooklyn 18, N.Y. (**A**)

Waner, John M., Motion Picture Film Dept., West Coast Div., Eastman Kodak Co. **Mail:** 4112 Arch Dr., North Hollywood, Calif. (**A**)

Welty, Thomas D., Assistant Construction & Operating Engineer, School of Music, Motion Picture and Broadcasting Studios, University of Washington. **Mail:** 12047 14th Ave., N.E., Seattle 55, Wash. (**A**)

Wolff, Alfred, Cinematographer, Lecturer. **Mail:** 3426 Elaine Place, Chicago, Ill. (**A**)

CHANGE OF GRADE

Gavey, Thomas W., Captain, U.S. Air Force. **Mail:** P.O. Box 2610, Washington, D.C. (**A**) to (**M**)

Chemical Corner

Edited by Irving M. Ewig for the Society's Laboratory Practice Committee. Suggestions should be sent to Society headquarters marked for the attention of Mr. Ewig.

New Uses of Glycerine An article by M. A. Lesser in the October 1949 issue of *Commercial Photography* describes some interesting uses of glycerine for removing negative scratches and as a wetting agent in developers for aiding the elimination of streaks.

Non-Skid Floor Wax "Cetox" is a high-gloss floor wax which is slip proof whether it is wet or dry because it's "hydraoxated." This product has the UL label and is manufactured by Chemical Service of Baltimore, Howard and West Streets, Baltimore 30, Md.

Fireproofing "Ruflan" is a flame retardent spray of plastic made by E. I. DuPont.

To Keep Chemicals Dry and Uncontaminated A convenient drum cover made of paper containing Neoprene. This is superior to wooden barrel heads and fiber covers or even metal drum lids for keeping chemicals in containers dry and in an uncontaminated condition. They are very easy to get on and off. The vendors are the Chase Bag Co., 1500 South Delaware Avenue, Philadelphia, Pa.

Disinfectant Soaps The Davies Young Soap Company, Dayton, Ohio, makes a concentrated soap with a high germicidal effect, "Germelin," which should be excellent for washing developing and water tanks and would go a long way toward the elimination of that Monday morning smell.

Prevention of Slime in Wash Tanks "Algex" is a phenolic derivative sold by the L. B. Russell Chemicals, Inc., of 60 Orange Street, Bloomfield, N.J. It is a good destroyer of slime and algae growths found frequently in wash tanks. It comes in convenient tablets which can be dropped in the bottom of the tank near the water inlet.

Stable Color Developer "Genochrome" is a derivative of p-aminodiethylaniline which has greater resistance to aerial oxidation and is less toxic than most color developers. The article describing this appears in *The Royal Photographic Society Color Group Bulletin*, No. 13. It is written by G. T. J. Field and D. H. O. John.

Conservation of Water Washing of film serves a dual purpose. The first is to remove soluble silver salts because, if allowed to remain, these cause staining and discoloration. The removal of silver salts is best insured by a two-bath system of fixation. The second function of washing is the removal of hypo. If allowed to remain in excessive concentrations will result in fading and discoloration.

The reduction of the hardening properties of the fixer, maintaining the wash water at as high a temperature as possible, adequate agitation, frequent changes of washing, avoiding contamination of each wash section by the use of squeegees, all aid in the reduction of the quantity of water required for washing. A complete story of this may be found in the article by J. I. Crabtree, "How to Save Water," appearing in *The Photographic Science and Technique Journal*, Section B, August 1950, pages 70–74.

Flow Meter The Builders-Providence Company, 419 Harris Ave., Providence 1, R.I., has designed a compact, easily installed, self-contained and self-operated flow meter, "Propeloflo." The flow through main or auxiliary pipelines is all that is needed to run this meter—no mercury, pressure piping, or electrical connections are required.

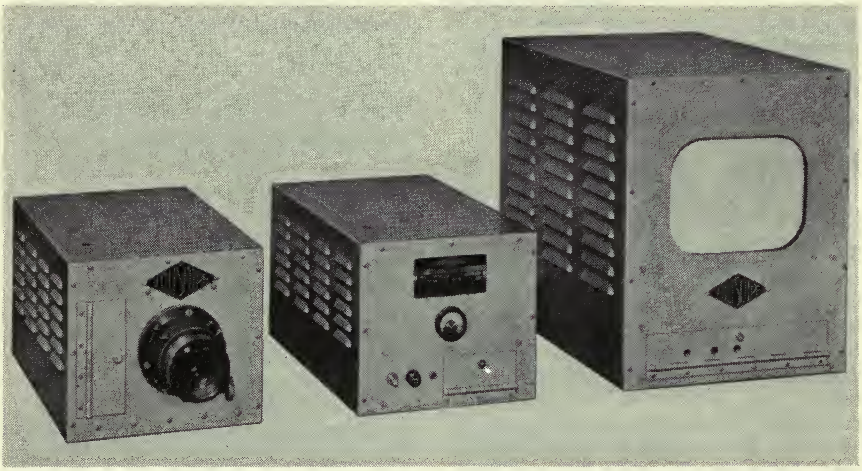
Make Your Own Distilled Water "Filtr-Ion" is a new and refillable ion-exchanger unit for small quantity uses which delivers water equal to triple distilled water. It is manufactured by LaMotte Chemical Products Co., Baltimore 4, Md.

This May Solve Your Dust Problem An easily applied, stainless "dust sealer" made by the West Disinfecting Co., 46-16 West St., Long Island City, N.Y., reduces dust to a minimum by leaving an antiseptic film to which dust adheres. This film is then easily removed. One gallon covers 4,000 sq ft.

A New Adhesive Tape This product is called #666 and is made by The Minnesota Mining Company. It is cellophane tape coated on both sides with adhesive for which many uses may be found in the laboratory. It does not fog or desensitize photographic material.

New Products

Further information about these items can be obtained from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.



The Utiliscope is a closed-circuit television system developed by Diamond Power Specialty Corp., Lancaster, Pa. Simplicity in circuits and controls is a basic feature of this industrial instrument. The receiver is a Farnsworth cold cathode, image-dissector, camera tube. The complete system of camera, power supply and monitor as shown in the illustration is designed for portability and weighs 110 lb. The power supply can be placed as far as 25 ft from the camera and the monitor can be up to 1000 ft away. The lens used as standard equipment is 90-mm, *f*/1.4, coated, focused by rack-and-pinion gear. A remote focusing drive can be incorporated, however.

Only 17 tubes, including the camera tube, are employed. A 10-in. picture tube is standard but 12- or 16-in. tubes can be substituted. The system has a 300-line resolution.

A trial use of the Utiliscope in a Hollywood motion picture studio is reported by W. W. Herlihy, Sales Service Engineer for the Diamond Power Specialty Corp. The possible effectiveness of a particular movie set for a forthcoming circus production was tested with the Utiliscope camera and power supply suspended on a small trapeze opposite the performers' trapeze in preference to building a scaffold to support a studio camera and two cameramen. A mannequin was used as the stand-in and the motion picture of the swinging trapeze was transmitted from the swinging camera to the receiving unit on the floor. After this inexpensive preview the director decided to abandon the scene, having incurred very little expense for the rejected shot.

Data on Random-Noise Requirements for Theater Television

By PIERRE MERTZ

Provisional evaluation of permissible random noise for theater television is considered from several sources of information. These cover broadcast television experience and the graininess in motion picture film; the requirements deduced from the various sources generally agree. For broadcast television, a frequency weighting and limit on weighted noise power have been used. The finer picture detail of theater television presumes a lower permissible random noise. Changes in weighting curve are discussed. A limit figure of noise is suggested, which is comparable to graininess effects in motion pictures, though slightly more severe than present published performance on camera tubes.

1. Introduction and Digest of Conclusions

A DEFINITIVE EVALUATION of the random noise which is permissible in theater television will need to be made, of course, with theater television equipment. In the meantime, certain deductions can be drawn from other sources to permit the estimate of a provisional figure which can eventually be checked.

In the first place, data can be examined, which have been obtained for the setting of random-noise requirements for 4-mc broadcast television. Though the solution of this problem is not definitive either, experience with it has indicated that at present the best, simple answer consists in weighting the frequency distribution of the random noise, and measuring the rms amplitude of the weighted noise wave, as compared with the peak-to-peak amplitude of the television video signal (from tip of synchronizing pulse to maximum white level). Then the effect of varying amounts of weighted noise upon a picture is submitted for judgment to a group of observers. They are given a set of preworded comments to use as criteria of impairments. The list is reproduced below.

1. Not perceptible;
2. Just perceptible;
3. Definitely perceptible, but only slight impairment to picture;
4. Impairment to picture, but not objectionable;
5. Somewhat objectionable;
6. Definitely objectionable; and
7. Not usable

To be noted, particularly, are comments No. 2, "just perceptible," and No. 4, "impairment to picture, but not objectionable."

With a picture of excellent quality by

Presented on May 1, 1951, at the Society's Convention in New York, by Pierre Mertz, Bell Telephone Laboratories, Inc., 463 West St., New York 14.

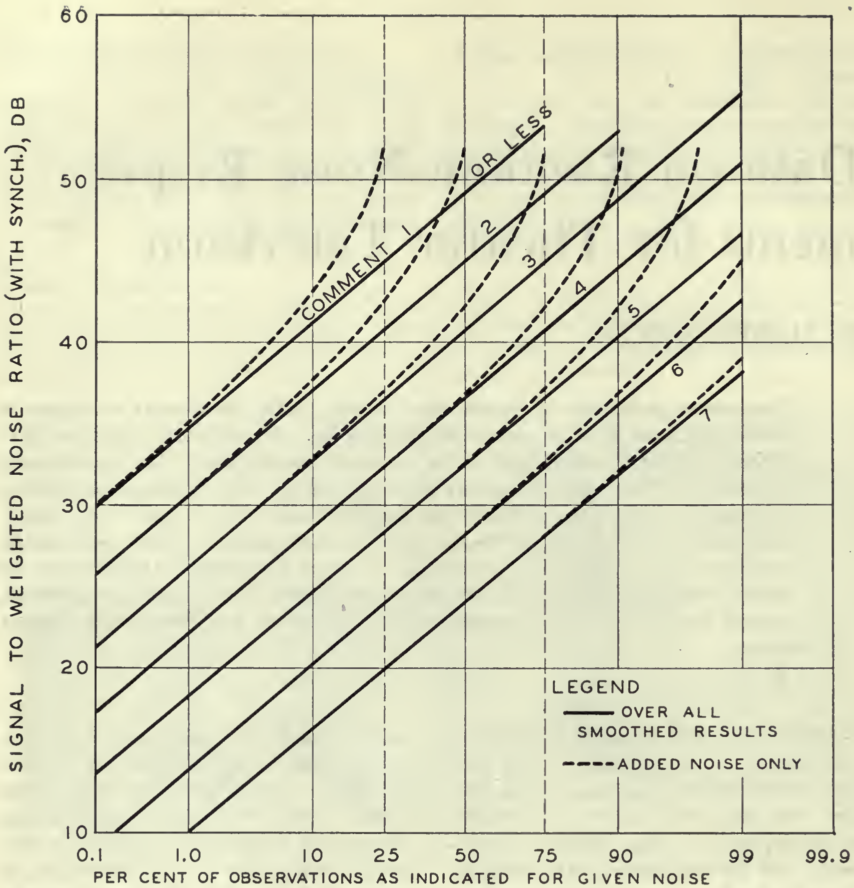


Fig. 1. Characterization of random noise on a television image.

present-day broadcast criteria, and using the 525-line and other current standards, and with the picture viewed at four times picture height, the pooled data on noise evaluation for three picture subjects are plotted, as smoothed for engineering use, in Fig. 1.

Examination of this shows that at a weighted noise somewhere between 40 and 50 db below the signal, 50% of the observers voted "comment No. 2 or less," i.e., they just begin to perceive the noise. Ninety per cent of the observers voted "comment No. 4 or less," i.e., the remaining 10% are just becoming conscious of the objectionable character of the noise. A figure of 46 to 47 db for the weighted noise has sometimes been used as an overall design objective. This corresponds to a figure of 44 db unweighted noise of flat distribution, or 40 db, if the distribution is "uptilted" or peaked toward the upper frequencies.

The weighting function to be used with Fig. 1 is again not definitive, but some of our best knowledge of it at present is plotted as curve I of Fig. 2.

The discussion which is presented below leads to the conclusion that for an 8-mc theater television system exactly

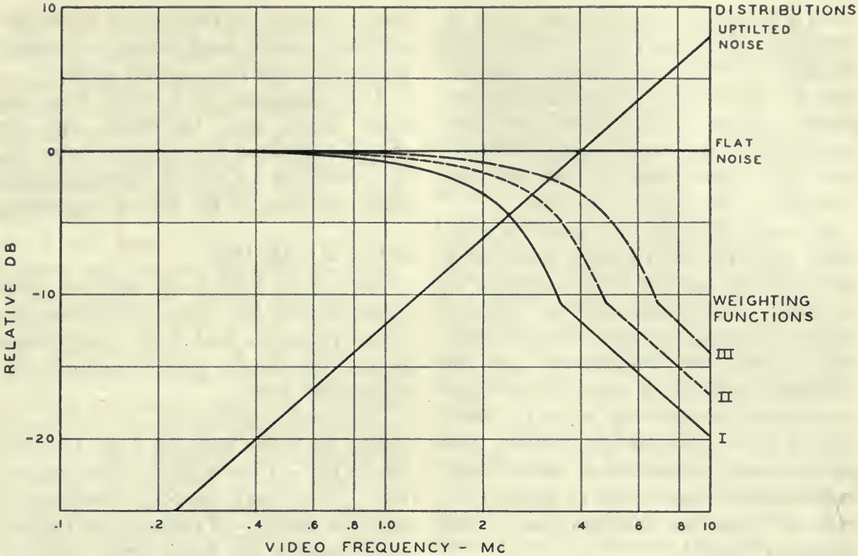


Fig. 2. Weighting functions and random-noise distributions.

the same plot as shown in Fig. 1 can be used provisionally. The weighting function to be used, however, is that indicated by curve III of Fig. 2. These indications assume that the system uses in the order of 740 scanning lines. If the broadcast standard of 525 lines is continued, and the frequency band merely widened to 8 mc, the weighting curve I is to be used, but the acceptable weighted noise reduced 3 db, i.e., the plots of Fig. 1 can be used, with the figures marked in the ordinates all increased numerically by 3 db.

These deductions all contain, either implicitly in the new weighting function or explicitly where the same weighting function continues to be used, a factor of 3 db greater severity in the requirement imposed. This is an estimate of the influence of the higher quality of the 8-mc theater television image (in the form of increased sharpness) as compared with the 4-mc image on which the data were taken.

Analogous figures have been reported by RCA, reached by means of a different philosophy, as will be discussed below. Their figure, translated into the terms which have just been used, is 50 db.

An obvious comment which can be made on the experiments used for plotting Fig. 1 is that they were carried out on a screen which was adequate in size for the testing of home viewing of broadcast television, but which was too small for the testing of theater television. There is evidence to show, however, that if the image subtends the same angle at the eye (which is controlled by setting the ratio of viewing distance to picture height), the results are very little dependent upon its absolute size.

A second estimate of permissible random noise in theater television pictures can be deduced from a study of the photographic graininess in present-day motion pictures. Although this graininess is perceptible to a watchful observer in a good seat, it is not obtrusive and not considered a problem by the motion picture industry. It can, therefore, serve as an index of how much of this impairment is acceptable. A simple deduction on the amount of this noise as derived from sound-track measurements indi-

cates a weighted signal-to-noise ratio, in television terms, of 47 to 52 db. Otto Schade of RCA has shown, however, that this deduction ignores certain important points. When these are taken into account, the result is not as definite, but the figures, less severe, are not changed by more than 2 or 3 db.

A third check to be made against these figures is the random noise being delivered by camera tubes available at present. The performance of these, of course, varies a great deal with the conditions of use, the adjustments and the individual tube being used. Some typical figures published by RCA (in addition to some informal information) give signal-to-noise ratios which, when translated into the same terms as used above, are, for broadcast television use, those shown in Table I.

Table I

Camera tube		*Signal-(peak-to-peak, including synch.) to-weighted noise ratio*
1850A	iconoscope	44 db
5655	image orthicon	44 db
5769	image orthicon	below above figure
5820	image orthicon	40 db
5826	image orthicon	43 db
1848	iconoscope	39 db
2P23	image orthicon	36 db

The best of these, therefore, formally miss the tentative overall design objective by 2 or 3 db, without allowance for contribution to noise from any other sources. It should be understood, of course, that new tubes are likely to be under development with better figures on noise performance.

A Bell Laboratories film scanner gives a signal-to-weighted noise ratio, in the above terms, estimated at 46 db. The data of Fig. 1 were taken with this signal source and, as taken, follow approximately the dotted lines. The solid lines represent an estimate in which the ordinates cover total noise (i.e., signal generator noise plus applied noise).

The indications as a whole from this third check are, therefore, that for theater television the random noise will be a problem not only for the connecting links, but also for the pickup apparatus.

2. Use of 4-Mc Data

Some data have been taken on noise requirements for 4-mc broadcast television channels, and a first approximation of the theater problem can be derived from them.

The major difference, of course, between the 8-mc and the 4-mc channels lies in the sharpness of the resulting picture. One may expect, consequently, that the viewer will measure the random noise against the finest detail which it obscures or distorts, and therefore to that extent he will be more critical of the 8-mc than of the 4-mc random noise. One can even propose, as probably reasonable, a principle that the viewer will consider equally objectionable, equal rms amplitudes of a "flat" distribution of random noise up to cutoff in the 4-mc channel and a similar "flat" distribution to cutoff in the 8-mc channel. This will be referred to below a number of times and will henceforth be merely called "the proposal." At the same viewing distance, the 8-mc band granulation would obviously be less visible than the 4-mc band granulation of the same amplitude, and the proposal amounts to making this difference in visibility a quantitative estimate of how much more critical the observer is in the case of the 8-mc picture than he is in the case of the 4-mc picture. If the proposal is taken as a guide, it means that with a "flat" distribution the total noise power in the 8-mc channel would be set at the same value which is acceptable for the 4-mc channel. This means that the tolerable noise power per kc of bandwidth is set at 3 db lower in the 8-mc than in the 4-mc channel.

M. W. Baldwin discovered experimentally, some time back,[1] that in a given television system the impairing effect of a flat "low-pass" distribution of random noise is measured largely by the noise power per kc, and is substantially independent of the upper cutoff. This means that if one uses this measure of how much more critical the viewer is expected to be, according to the proposal, of 8-mc than of 4-mc television, it amounts to a 3-db difference in admissible random noise. In the same experimentation it was also found that for equal impairing effect the random-noise power is raised 6 db for a doubling of the viewing distance. A measure of the expected reaction in the observer, according to the proposal, therefore, also corresponds to a reduction, in the ratio of 1 to $\sqrt{2}$, in the minimum viewing distance for which the system is to be engineered for 8 as compared to 4 mc.

There are other grounds for considering the proposal to be reasonable. These are that the added fine detail signal in going from a 4-mc to an 8-mc band is lower on a power-per-kc basis than the signal already existing in the 4-mc band. General typical indications are that the average signal power per kc at 8 mc is $\frac{1}{4}$ that at 4 mc. The average power per kc of the added signal would, therefore, be somewhere between equality and $\frac{1}{4}$ of that at the 4-mc cutoff. The noise power per kc in the band between 4 and 8 mc, for the 8-mc system, as set by the proposal, is just half that in the 4-mc system. Half happens to be the mean proportion between 1 and $\frac{1}{4}$. Thus, on the new detail, added between 4 and 8 mc, the signal-to-noise ratio, to at least its mean proportional, is kept at the figure maintained in the 4-mc system at 4 mc. There is, of course, an improvement of 3 db in the signal-to-noise ratio between 0 and 4 mc, which is one of the factors contributing to the improved quality of the 8-mc over the 4-mc system. The consequences of the proposal, when increasing the bandwidth from 4 to 8 mc, may be examined in more detail.

For Case I it will be assumed that the number of scanning lines is not changed in going from 4 to 8 mc. Diagrams of the two observed pictures are illustrated in Fig. 3, each viewed at four times picture height. The scanning-line structure will be identical in the two cases. The finest horizontal detail that can be seen in the 8-mc picture at (b) is, however, twice as fine as in the 4-mc picture at (a). This is indicated schematically by marks which are proportional to cycle marks in the two. At (a), the 4-mc cycle marks will have exactly twice the spacing that the 8-mc marks have at (b).

The theory that was presented in the paper on "Perception of Television Random Noise,"[1] indicates that the simplified noise-weighting curve presented there for a four-times-picture-height viewing distance is merely extended from 4 to 8 mc. This is illustrated by curve I of Fig. 2. It is to be noted, by reference to the original paper, that under the conditions then used in the experiment most of the weighting was visual, i.e., in the eyes of the observer. The picture tube used contributed somewhat, estimated at about a third to a quarter of the final effect. In Fig. 2 this double source of the weighting is ignored.

For Case II it will be assumed that the number of scanning lines in the 8-mc system is increased, in the ratio of $\sqrt{2}$ to 1, to that in the 4-mc system. This is illustrated in Fig. 4. Fig. 4(a) is merely a duplication of Fig. 3(a). The solid lines in Fig. 4(b) are a duplication of Fig. 3(b), except for the cycle marks. Since the number of scanning lines has been increased in the ratio $\sqrt{2}$ to 1, the horizontal speed of tracing them has been increased in the same ratio. Thus, the 8-mc cycle marks no longer have half the spacing of the 4-mc cycle marks in (a); they now have $1/\sqrt{2}$ times the spacing of the latter.

Inside of Fig. 4(b), in dotted outline, is

a picture frame that covers the same number of scanning lines vertically as used in the 4-mc system of Fig. 4(a). It therefore has $1/\sqrt{2}$ times the vertical height of the picture in solid lines. The remainder of the picture frame is drawn in to the same scale, i.e., its width is $1/\sqrt{2}$ times that of the one in solid lines. The cycle marks are shown with exactly the same spacing as the 8-mc cycle marks in the picture with solid lines.

It will be noted that, except for its absolute size, which is reduced in scale in the ratio of 1 to $\sqrt{2}$, the dotted-line picture of Fig. 4(b) has exactly the same objective capabilities for rendering detail, with the 8-mc band, that Fig. 4(a) has with its 4-mc band. It will also objectively render random noise in exactly the same way, provided the instantaneous time scale of the noise is stretched in the ratio of 2 to 1, because the cycle marks at 8 mc in Fig. 4(b) have exactly the same proportionate spacing to the frame that they have in Fig. 4(a) at 4 mc. The dotted picture in Fig. 4(b) is viewed at $4\sqrt{2} = 5.65$ times picture height. Thus, noise will be seen in Fig. 4(b) in exactly the same way as in the 4-mc picture of Fig. 4(a) viewed at 5.65 times picture height, but with the noise-frequency scale stretched from 4 mc to 8 mc. If the source of the weighting is ascribed to the eyes of the observer alone, and the picture-tube contribution ignored, the noise-weighting curve for Fig. 4(b) is that for Fig. 4(a), viewed at 5.65 times picture height, stretched on the frequency scale so that the 4-mc point appears at 8 mc. This weighting curve is shown at II in Fig. 2.

We do not contemplate setting the noise for the 8-mc channel in Fig. 4(b) equal in absolute perceptibility to that for the 4-mc channel in Fig. 4(a), but it will be of some interest to examine what this leads to.

What is involved in the proposal, in terms of Fig. 4(b), is to engineer the 8-mc system in terms of a viewing distance that permits the fine detail in the dotted-line frame to be equal to that seen in Fig. 4(a). This is accomplished by reducing the viewing distance to $4/\sqrt{2}$ or to 2.83 times picture height. This has been done in Fig. 5(b) and will represent Case III.

Figure 5(a) is again a duplication of Figs. 3(a) and 4(a). The dotted-line picture in Fig. 5(b) is also exactly the same in objective representation of detail. The dotted cycle marks in Fig. 5(b) are spaced exactly the same as in Fig. 5(a), but represent 8-mc cycles instead of 4-mc cycles. Then the solid lines in Fig. 5(b) are scaled up in the ratio of the $\sqrt{2}$ to 1 about the dotted lines, except for the cycle marks, which are kept at the same 8-mc spacing. The solid lines represent the complete picture transmitted by the 8-mc band viewed at 2.83 times picture height, according to the consequences of the proposal. The noise-weighting curve for Fig. 5(b) is, therefore, the same as that used for Fig. 5(a), except that it is stretched along the frequency scale so that the 4-mc point appears at 8 mc. This is shown by curve III in Fig. 2.

With this background, relations between the various cumulated weighted power requirements can be deduced for the three cases considered, first, under assumptions of equal absolute noise perception between the 4- and 8-mc bands, and then, under the proposed assumption of a somewhat more severe requirement for the 8-mc band. To correlate the results with two distributions of noise, approximated in practice, the weighted power ratios can then be translated into unweighted power ratios for those distributions. The distributions are illustrated in Fig. 2; they are the "flat," already mentioned, and the "uptilted," rising with frequency up to the cutoff point at the rate of 6 db per octave. The relations have been summarized in Table II.

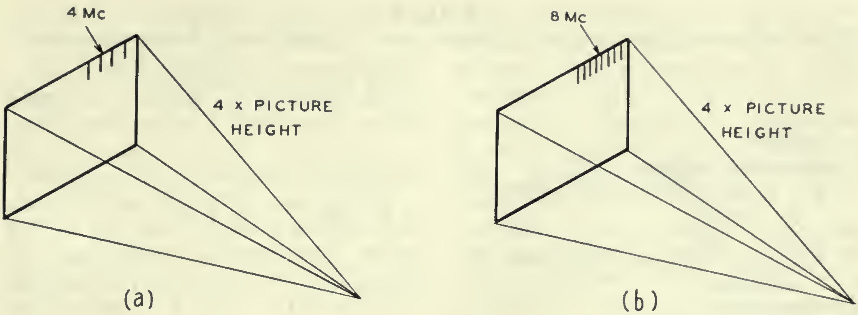


Fig. 3. Viewed 4-mc (a) and 8-mc (b) pictures. No change in scanning lines.

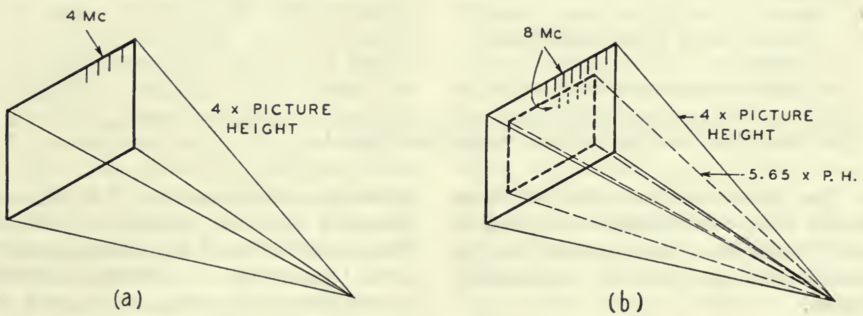


Fig. 4. Viewed 4-mc (a) and 8-mc (b) pictures. Scanning-line ratio 1: $\sqrt{2}$. No change in viewing distance.

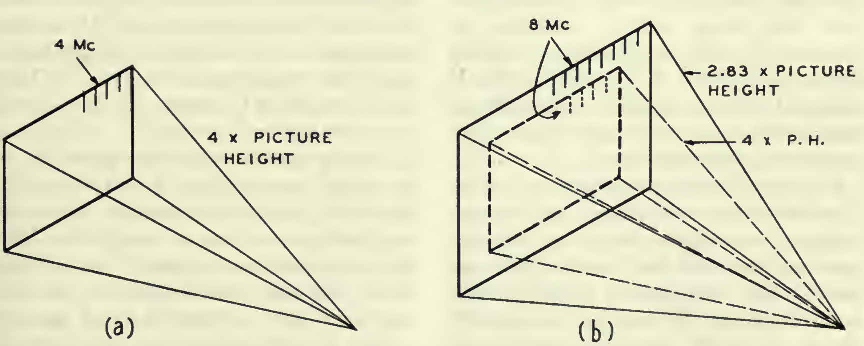


Fig. 5. Viewed 4-mc (a) and 8-mc (b) pictures. Scanning-line ratio 1: $\sqrt{2}$. Viewing-distance ratio $\sqrt{2}$: 1.

Table II

	Cases I	Cases II	Cases III
A. *Weighted*			
Equal absolute perception			
Flat or uptilted noise, 8 mc above 4-mc* power	0 db	1.5 db	
Proposal			
Flat or uptilted noise, 8 mc above 4-mc* power	−2.8		0 db
B. *Unweighted*			
Equal absolute perception			
Flat noise, 8 mc above 4-mc* power	2.8	2.8	
Uptilted noise, 8 mc above 4-mc* power	6.4	4.7	
Uptilted above flat noise, 4 mc	3.5		
Uptilted 8 mc, above flat 4 mc*	9.9	8.2	
Proposal			
Flat noise, 8 mc above 4-mc* power	0		0
Uptilted noise, 8 mc above 4-mc* power	3.6		0
Uptilted 8 mc, above flat 4 mc*	7.1		3.5

* Distribution up to 4 mc using the weighting of Case I

The basic data from which the items in the table are calculated are given in the Appendix. Explanations of the calculations are outlined immediately below.

For absolute equal perception in Case I, the weighted noise, either flat or uptilted, should be the same for the 4 and 8 mc, this, of course, being the objective of the weighting. For Case II, the closer scanning lines in Fig. 4(b) as compared with Fig. 4(a), which can also be measured by the difference in viewing distances, lead to a rise of 1.5 db in weighted noise from the 4- to the 8-mc band. This can be determined from equation (5) of reference 1.

For the proposal, the objective in Case I, as has been noted, is to set the unweighted cumulated flat noise requirement the same for the 8- as for the 4-mc band. The weighting to a sharp cutoff at 4 mc reduces the total power by 2.87 db as compared with the unweighted power (to the same sharp cutoff). The weighting to a sharp cutoff at 8 mc reduces the total power by 5.64 db as compared with the unweighted power. Thus, application of the proposal leads to the requirement for the 8-mc channel of a weighted total noise power which is $5.64 - 2.87 = 2.77$ db lower than for the 4-mc channel. In each case the same curve I of Fig. 2 is used as the weighting function.

The objective in Case III is to set the requirement for the 8-mc weighted noise (with the weighting of curve III) at the same value as for the 4-mc weighted noise (with the weighting of curve I). This ratio then holds for other distributions of noise, including "uptilted."

Taking up the first item under B, in the table, under Case I and from the Appendix, the drop for flat noise in weighted power from unweighted is 2.87 db for 4 mc, and 5.64 db for 8 mc. Thus, the net permissible rise in unweighted power, from 4 to 8 mc, is $-2.87 + 5.64 = 2.77$ db. For Case II the respective figures are -2.87 and $+4.21$ db, but there is a differential of

1.5 db in weighted power, giving $-2.87 + 4.21 + 1.5 = 2.84$ db.

For uptilted noise the corresponding figures are $-6.34 + 12.72 = 6.38$ db for Case I, and $-6.34 + 9.56 + 1.5 = 4.72$ db.

At 4 mc the permissible unweighted uptilted noise, above flat noise, is $6.34 - 2.87 = 3.47$ db. At 8 mc the permissible unweighted uptilted noise, above flat noise at 4 mc, is $12.72 - 2.87 = 9.85$ db, for Case I. For Case III, it is $9.56 - 2.87 + 1.5 = 8.19$ db.

In the next group of items, covering the proposal, the first comes back to the original objective for Case I, namely that the 8-mc flat unweighted noise be placed at the same level as the similar 4-mc noise. For Case III, the weightings to 8 mc on curve III and to 4 mc on curve I give the same drop from flat unweighted to weighted noise, namely 2.87 db. This keeps the difference zero for the unweighted, as it did for the weighted noise. This also holds for uptilted noise in Case III, the drop here being 6.34 (or 6.35) db for each. For Case I, on this last item, the figures are $12.72 - 6.34 - 2.77 = 3.61$ db.

Finally, the uptilted 8-mc noise, above flat 4-mc noise, each unweighted and for Case I, is $3.61 + 3.47 = 7.08$ db. For Case III, the figures are $0 + 3.47 = 3.47$ db.

It is to be understood, of course, that the small fractions of db which are kept in the figures above are purely for the sake of internal consistency in the table, and do not pretend to imply such precision in knowledge of the correct weighting.

There have been many analyses of the random noise permissible in a broadcast television channel. Perhaps the most comprehensive of recent tests were carried out together with others presented in a paper[3] before the IRE Convention in March 1950. The reactions of observers to random noise in a television picture were determined, as expressed by preworded comments. The signal used followed the 525-line and other current broadcast standards. The pictures were observed under critical viewing conditions and were of excellent quality as considered by present-day broadcast television criteria. The highlight luminance and contrast ratio varied from picture to picture, in order to adjust to the best image in each case. The first ranged from 42 to 65 mL, and the second, from 26 : 1 to 130 : 1. The resulting data are shown summarized in Fig. 1. The dotted lines cover the effect of noise already existing in the film scanner used to generate the signal, and can be ignored for the moment. They will be discussed again below in connection with the noise originating in pickup devices.

The ordinates of Fig. 1 are plotted as signal-(peak-to-peak, including synchronizing pulses)to-weighted rms noise (weighted according to curve I of Fig. 2) ratio. Following the proposal made above, the curves can be used as they stand for the 8-mc band, if the noise is weighted according to curve III of Fig. 2, provided the number of scanning lines in the 8-mc system is raised from 525 to 741. If the number of lines is kept at 525, then according to the discussion the acceptable weighted noise power is reduced by 2.7 db. That is, the ordinates should be labeled with figures numerically 2.7 db (say, rounded to 3 db) greater, and the weighting curve I of Fig. 2 used.

The data for Fig. 1 were taken on a television picture 6×8 in., and it would be natural to question them for application to a theater-screen-size picture, even if the solid angle subtended at the eye were the same. In 1941 there were doubts of a similar kind, directed particularly at the sharpness perception of the observer to detail in the picture.[2] These existed particularly because of earlier data indicating a loss of visual acuity for near vision. The 1941 results indicated the earlier information to have been much exaggerated, and perception

to be fairly closely the same over the visual range of accommodation. The change in visual acuity, according to Luckiesh and Moss, is about 16%, and, according to unpublished experiments of Baldwin, about 4%. While data on the larger screen are eventually desirable, the curves of Fig. 1 are acceptable provisionally.

3. Photographic Graininess Data (Sound Track)

Film graininess has been an important problem for the motion picture engineer from the start, and there is much literature on the matter.[4] Simple quantitative data on the subject come from the use of film for sound track, of the variable-density type. A brief review of the data are given in an unpublished report presented by Dr. Otto Sandvik to the Subcommittee on Distribution Facilities of the Committee on Theater Television of the SMPTE.

The sound track is scanned by an aperture, 0.084 in. wide and 0.001 in. long (i.e., in the direction of motion). The sound system transmission is substantially flat from 50 cycles to 10 kc. The signal-to-noise ratio on such a system is of the order of 45 db. This is under optimum conditions, and it is more likely to be of the order of 40 db. These are the basic figures, before schemes of noise reduction, which cannot be employed in the picture, are used.

In order to interpret these figures in terms of pictorial representation it is necessary to know how the noise and signal are measured. The noise is measured by its rms amplitude. The signal is measured by the rms amplitude of a sine wave that is printed at an average diffuse density which is understood to be of about 0.6 in the film (transmission 25%) and to have an order of 8-db margin against a sine wave whose peaks just saturate on the zero transmission side. The usual method of expressing this ratio in the television art is to measure the noise by its rms amplitude, as here, but the signal is measured by its peak-to-peak amplitude. In a general way, the picture in a film runs from nearly zero transmission to some 80% transmission. Thus, the following corrections are needed to translate from the sound signal to the picture signal:

3 db	rms to peak-to-zero
6	peak-to-zero to peak-to-peak
8	margin, peak-to-peak
4	50% to 80% transmission range
21 db	total

In addition, television measurements are usually expressed with respect to a signal wave including the synchronizing pulse, which is some 2.5 db greater in peak-to-peak amplitude than a signal wave including only the picture. Thus, this figure should be added, giving a final correction of 23.5 db. This gives 68.5 db and 63.5 db, respectively, for the optimum and typical figures.

The next step involved in the interpretation is to correct for the aperture spot size, which is, of course, not the sound-track scanning-aperture size. An 8-mc theater television system of 741 lines ($525\sqrt{2}$) will be assumed. This has 700 unblanked lines, and there are 590 half-cycles of the 8-mc wave along the unblanked length of a scanning line. Thus, the aperture spot size as measured on the film is 0.905×1.46 mils. It has an area of 1.32 sq mils, as compared with the 84 sq mils of the sound-track aperture. Graininess distribution is approximately a normal distribution,[4] or its spectrum is approximately flat, so that the power ratio correction is very closely the area correction. This is 64 to 1, or 18 db, which must be subtracted from the signal-to-noise ratio which has been mentioned above.

There is an additional correction to be made for the difference in repetition rate between motion picture frames and complete television frames, which affects the storage of the visual perception. When the flicker is imperceptible, this is

approximately in the ratio of the repetition rates for the noise power. This is 30/24, or about 1 db, which changes the 18 db above to 19 db.

Since the noise spectrum is flat, the weighting, with curve III of Fig. 2, requires a further numerical addition of 2.9 db, changing the 19 db to 16 db.

Thus, it is simply deduced that for theater television the weighted random noise corresponding to motion picture graininess is slightly over 52 db under optimum conditions, and slightly over 47 db under more usual release-print conditions.

Dr. Sandvik also refers to some figures presented by Otto H. Schade in the *RCA Review*[5] (p. 36, Mar. 1948). These are based on a Fechner fraction of 2% [see his equation (18)], but are said to be in substantial agreement with values observed on high-quality 35-mm film. They come out, respectively, (unweighted) 37 and 33 db, for 500- and 800-line systems. The signal basis is $\bar{B}$, or average scene luminance (average over the frame). The average, from frame to frame, has been investigated[6] and found, for black-and-white feature films, to be of the order of $\frac{1}{5}$ the maximum. It is obviously glib to substitute this for the average over the frame, but the order of magnitude appears right. Thus, there should be added 14 db, plus 2.5 db for synchronizing signal, less 1 db for frame-speed ratios, and plus 2.9 db for weighting. The result is slightly over 51 db for the 800-line system. This is admittedly rough and ready, but in agreement with the previous figure.

It may be noted that Schade, in the reference which has just been quoted[5] has given a further estimate, which he entitled "Threshold Signal-to-Noise Ratios Required for High Quality" (*RCA Review*, p. 283, June 1948). These are for a 4-mc channel rather than for theater television, and are not derived directly from graininess data but from threshold visibility on a picture tube. They are, nevertheless, of interest here. They are for a picture of 32-ft-L highlight luminance, viewed at four times picture height, and do not include the 2.5-db allowance for synchronizing pulse. The figures are:

Flat noise. . . . . .50–54 db
"Peaked" noise (uptilted) 40–48 db

These figures are more severe than the ones quoted by Sandvik. The figures are for unweighted noise, and it is noted that the difference ranges from 6 to 10 db between the uptilted and flat noise requirements, as compared with differences for the weightings of Fig. 2 ranging from 3.4 to 7.1 db. This indicates somewhat sharper weighting functions than are shown in Fig. 2.

This difference will be found to occur in a number of instances in the present report. Examination of the discussion of the weighting function by Schade indicates that he conceives of it as describing a filtering phenomenon which is the same for single-frequency bars as for random-noise grains, and for which he has determined the characteristics from bar patterns. However, it is to be noted that experiments with bar patterns have indicated a rise of threshold amplitude with frequency[7] (near the upper portion of the video frequency range) at the rate of 12 db per octave. Experiments with random noise[1] (resulting in the weighting of Fig. 2) indicate a corresponding rise of only 6 db per octave. While the question does need to be resolved, the weighting of Fig. 2 is considered, for the moment, safer than the steeper function used by RCA authors.

Sandvik further refers to some figures of Jones and Higgins on granularity. These will be discussed in Section 4 below.

4. Photographic Graininess Data (Picture)

In a paper presented orally before a meeting of the Subcommittee on Interconnecting Facilities, Schade has pointed out the oversimplifications in some of the

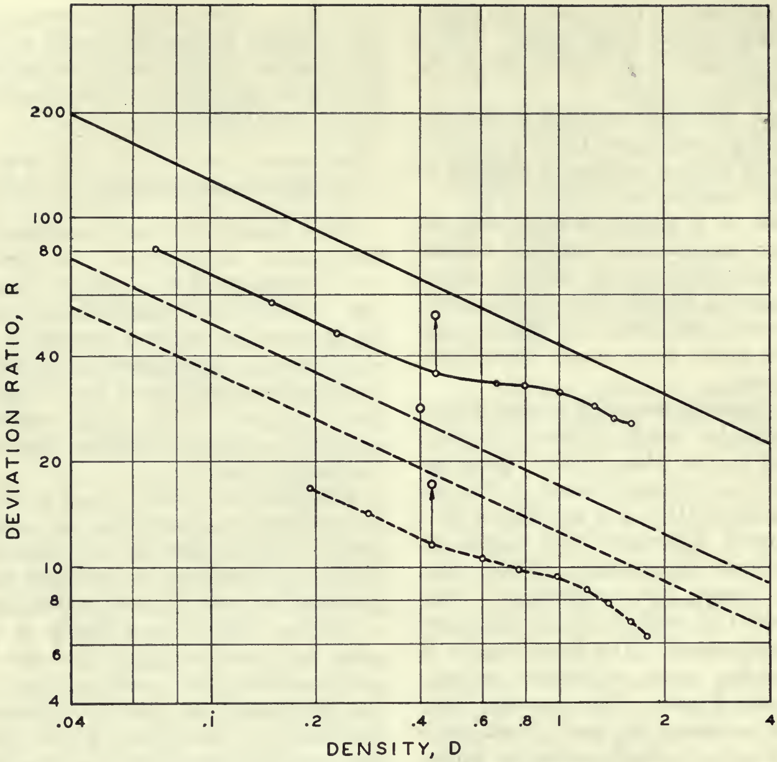


Fig. 6. Graininess variation with density.
———Fine grain—Pos. 1302; Neg. 1203
— — —Plus X — — — — —Super XX
Straight lines, Schade; points, Jones & Higgins

deductions in the previous section. These are chiefly:

(a) The grain structure in photographic film does not enter into the picture, as a function of density, in the same manner as does random noise in a television picture as a function of local luminance (say, measured in terms of equivalent density below highlight luminance).

(b) The translation between electrical signal voltage and picture luminance is not usually linear.

Schade notes that the law of variation of granularity (expressed as a standard deviation of local transmittance divided by average local transmittance) with density, in a single film, is as the square root of the latter. That is,

$$\Delta T/T = k_1 \sqrt{D}, \qquad (1)$$

where

T = transmittance,
ΔT = standard deviation of transmittance,
D = density = $\log_{10}(1/T)$,
k_1 = a constant.

He frequently uses the reciprocal $R = T/\Delta T$, in which case:

$$R = 1/(k_1 \sqrt{D}). \qquad (2)$$

Because photographic graininess follows an approximately normal law, R can be taken as proportional to the diameter of

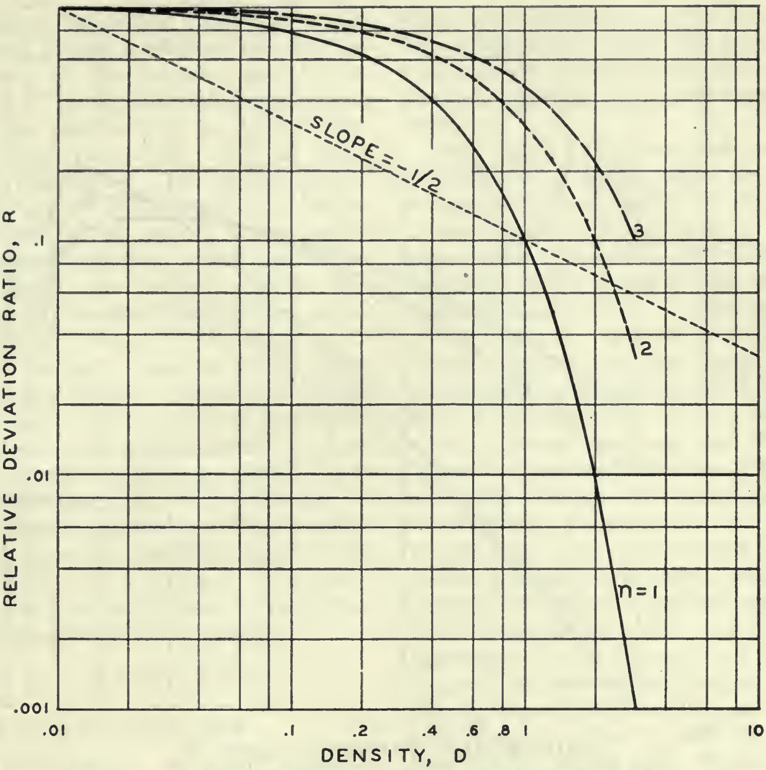


Fig. 7. Noise equivalent to graininess variation with density.

the sampling aperture used in measuring the graininess.

A plot summarizing Schade's measurements is compared in Fig. 6 with the results reported by Jones and Higgins[8] (p. 203, 1946). The connected points were measured by the Selwyn method, the isolated points by the Goetz and Gould method, and data for various sizes of aperture have been corrected to that for a diameter of 30μ (1 micron = 1μ = 10^{-6} meter = 10^{-3} mm) for which the Schade data are presented. It is not likely that the films referred to are the same. The intermediate film is known to be different, i.e., Plus X for the Schade data and Panatomic X for the Jones–Higgins data. Considering this, and differences in actual samples and development, and also the differences in measurements of the same films by two different methods, the data of Fig. 6 represent a good check.

If the television receiving system reproduced picture luminance (or therefore also equivalent transmittance) were directly proportional to signal voltage and the noise were of a simple additive type, then ΔT in equation (1) would be a constant independent of T or D. Calling this k_2:

$$\Delta T = k_2 \tag{3}$$

$$R = T/\Delta T = T/k_2. \tag{4}$$

Thus, the ratio, R is proportional to T. Putting the constant k_2 as 1, this leads to the curve marked $n = 1$ in Fig. 7, which plots relative R as a function of density. The curve for this simple con-

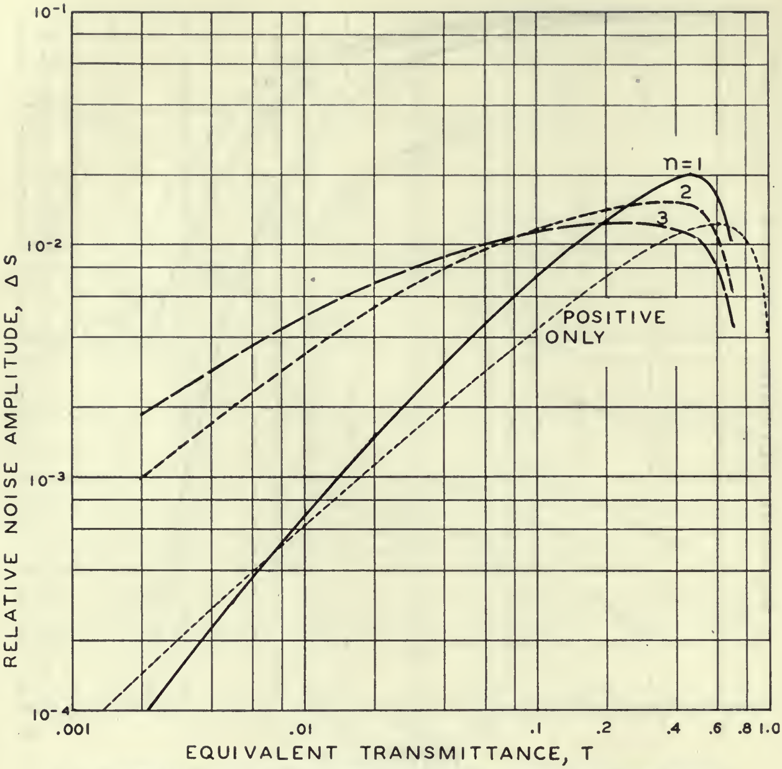


Fig. 8. Noise equivalent to graininess variation with transmittance.

ception of a television system is seen to be different from that obtained in a single film, exemplified by the line of slope $-\frac{1}{2}$.

The television receiver may be complicated somewhat by making the transmittance proportional to some power, n, of the signal voltage. That is,

$$T = k_3S^n, \tag{5}$$

where

S = signal voltage,
k_3 = a constant.

Then:

$$\Delta T/T = k_3n\Delta S/S \tag{6}$$

$$R = T/\Delta T = S/(\Delta Sk_3n) \tag{7}$$

$$= (T/k_3)^{1/n}/(k_3n\Delta S) \tag{8}$$

$$R = T^{1/n}k_4, \tag{9}$$

where:

$$k_4 = k_3{}^{1/n}/(k_3n\Delta S).$$

Most actual television receivers follow a law in which n has some value between 2 and 3. The plots of relative R for these values, assuming in each case k_4 as equal to 1, are indicated in Fig. 7. They represent a slightly better fit than for $n = 1$, only, however, in that the general slope tends to be somewhat closer to $-\frac{1}{2}$.

Schade points out, furthermore, that actual motion picture film, as projected on a screen, is more complicated than a single emulsion. It consists of a negative printed on a positive, which is projected through an optical system. The emulsion having the greater graininess is usually the negative, because the

stakes in higher film speed (and consequently greater graininess) are more important for the negative than for the print. The negative graininess is printed on the positive with an inverse density scale (i.e., black turns to white, and vice versa). The graininess contribution of the negative is further changed by the gamma of the positive emulsion and by a small amount of blurring in the printing process. Finally, the graininess of the positive print is somewhat reduced in projection by the small amount of blurring in the optical projection process. Schade goes through estimates of all these effects, and finally ends with a deviation ratio, R, as a function of the equivalent density, D, or transmittance, T, of the picture as projected on the screen. This is plotted in a somewhat modified form, as the curve for $n = 1$ in Fig. 8. The modification is obtained from a transformation of equation (8) by placing:

$$k_5 = 1/(k_3 \cdot k_3{}^{1/n}).$$

Then,

$$\Delta S = k_5 T^{1/n}/(nR). \tag{10}$$

The curve for $n = 1$ then represents ΔS as a function of T for k_5 and n, each equal to 1. In a simple transmission system having a receiver characteristic for which $n = 1$, the quantity ΔS, representing the rms value of the superposed noise, would be independent of the instantaneous magnitude of the signal or of its corresponding screen luminance, and would thus be represented as a constant in Fig. 8. The curve, however, shows how it must vary with the relative screen luminance to correspond with the effect obtained from the composite photographic graininess as deduced by Schade.

To show the effect of taking account of the negative graininess and the other factors, the fine-dotted curve marked "positive only" in Fig. 8 is a reproduction, in the transformed coordinates, of the straight line for fine-grain film of Fig. 6. The blurring effects more than compensate for the graininess contribution from the negative, in the very extreme highlights, where the equivalent noise of the positive graininess alone comes out greater than for the composite effect.

The curves have also been plotted showing the equivalent noise, ΔS, for a simple transmission system where the receiver characteristic has the more usual exponents $n = 2$ and 3. For these the equivalent noise is much more nearly constant than for $n = 1$. Nevertheless, it does show a range of equivalence, which indicates that the incidence of photographic graininess is not wholly the same as that of additive random noise.

In an actual receiving tube the exponent, n, is approximately constant only over a range of luminances, and drops deeply toward the lowest luminances used. The equivalence in Fig. 8, therefore, departs even further than suggested, for the very low transmittances.

The equivalence which is of greatest significance is, of course, that which occurs in the transmittance region of the picture where the noise is most visible. Unfortunately, this is not too well known at the present time. However, in the same communication, Schade presents the results of some threshold measurements of random noise as a function of the picture luminance where the noise is perceived. A replot of his curve, for noise perceived on picture modulated fields, is shown in Fig. 9, translated into the same coordinates as Fig. 8. His curve has been translated to 15 ft-L equal 100% transmittance.

The fact that the curves run below those for the same indices in Fig. 8, in some part of the transmittance range, indicates that the photographic graininess for which Fig. 8 is plotted will be above threshold for those transmittances. This is consistent with the statements which have been made before. The margin runs in the order of 5 db and is at its maximum in the transmittance region between 0.15 and 0.3. If a constant additive noise were superposed, of a

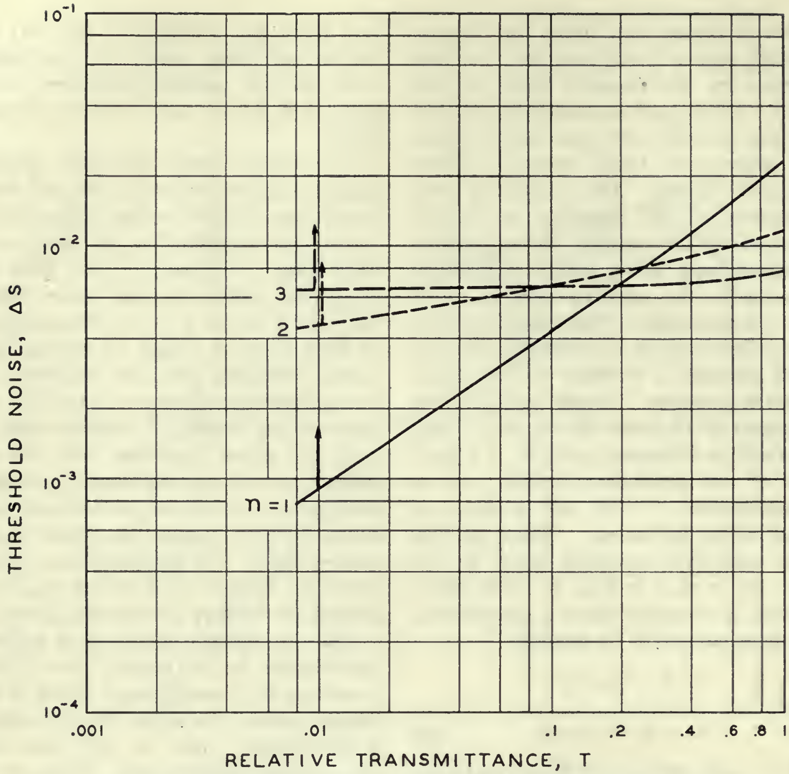


Fig. 9. Threshold noise—variation with transmittance.

value indicated at the point of maximum margin of visibility over threshold, it would appear worse than the graininess portrayed in Fig. 8, because the margin of visibility over threshold would be greater in the lower transmittances. To obtain a constant additive noise showing about the same picture impairment as the photographic graininess, the margin of visibility of the latter has been translated to the region of greatest susceptibility, i.e., in Fig. 9, of lowest transmittance, which has arbitrarily been taken as 0.01. (There might be some question as to whether, in consequence of the remarks made regarding Fig. 8, this is not too low for validity in actual receivers.) Under these conditions the noise equivalences are (measured to the signal at 100% transmittance):

n = 1	55 db
2	42
3	38.

These are indicated by the tips of the arrows at the left end of the curves in Fig. 8. The figures need further corrections as follows:

+2.5 db	ratio of effective apertures (44μ diam to 1.32 mils^2)
−1.	ratio of frame rates
+2.5	addition of synchronizing pulse
+2.9	frequency weighting
6.9	net
say, +7	(rounded)

Thus, the figures above deduced are changed to:

n = 1	62 db
2	49
3	45.

These figures, ignoring the case for $n = 1$, are slightly more lenient than, but in substantial agreement with, those derived from sound-track data. They are somewhat suspect for two reasons. First, the aperture data imply a poorer projected-film picture than television picture, which does not appear wholly reasonable. In the second place, the random noise is shown to be first perceived in the extreme blacks, which is contrary to general observation. This is caused by the trend of the curves in Fig. 9, which does not show the usual rise of threshold noise to a constant toward low luminances, which again is the indication of deviation from the Weber–Fechner law.

In a general way, it can be said that while the discussion of the detailed points has clarified our understanding of the relationship between photographic graininess and random noise, it has not seriously changed the conclusions from the simple sound-track deductions.

Schade has also compared the incidence of noise in the image orthicon camera with that of photographic graininess. This correlates somewhat more closely than that of the additive noise in the simple circuit. Computing this noise to threshold leads to a requirement of 45 db to the maximum picture signal. This is corrected to 42 db by the change from 4 to 8 mc (i.e., without the change of observer viewing distance involved in the proposal which has been made above). By allotting a contribution of 6 db below this to "video amplifiers or signal distribution systems," the figure of 48 db is reached. To allow for superposition of the synchronizing signal, 2.5 db should be added to this and for conversion to weighted noise, 5.6 db should be added to the 8-mc figure, and 2.9 db to the 4-mc figure. Both, then, lead to 50-db weighted noise overall, and 56 db allocated to the electrical transmission. This allocation has not been made in any of the other figures presented, which merely deal with overall requirements.

5. Noise Data on Pickup Equipment

Some modern television pickup tubes have been described recently in the *RCA Review*,[9] and their signal-to-noise ratios are estimated under reasonably typical lighting conditions as adapted to their respective uses.

The 1850A iconoscope (photocathode image area, 17 sq in.) is estimated to have an unweighted signal-to-noise ratio of 35.6 db. With synchronizing pulse, this becomes 38 + db. This is a "peaked" or "uptilted" noise, and the equivalent flat noise is estimated in the paper at 45.1 db (with synchronizing pulse 48 − db). The allowance for the "uptilted" over the flat noise is, therefore, assumed at 9 to 10 db, compared with the 3.4 db which has been deduced above. This discrepancy in weighting has already been noted. Using the weighting of Fig. 2, the weighted figure would be 44 + db (with synchronization).

The 1848 iconoscope (photocathode image area, 6 sq in.) is estimated as having an unweighted signal-to-noise ratio of 29.8 db (with synchronizing pulse 32 db). This noise is characterized as "not always acceptable." The noise is also "peaked," and, using the weighting of Fig. 2, the figure would be 39 − db.

The 2P23 image orthicon (photocathode image area, 1.23 sq in.) is estimated as having, with the original gun design, an unweighted signal-to-noise ratio of 28 db (with synchronizing pulse 30 + db). With a new gun design this was raised to 30.9 db (with synchronizing pulse 33 + db). This is a "flat" noise, and no extra allowance is due. However, weighted noise (with the weighting of Fig. 2) would be 36+ db. The performance from the standpoint of noise is characterized in the paper by the statement, "Although this value is on the low side, it is acceptable for outside pickups."

The 5655 image orthicon (photocathode image area, 1.23 sq in.) is

Table III

	Distribution	
	Flat	*Uptilted*
Sharp cutoff to 4 mc		
Integrated, unweighted power	0	−4.77* db
Unweighted/weighted power, curve I	2.87	6.34
Unweighted/weighted power, curve II	1.66	3.30
Unweighted/weighted power, curve III	0.90	1.60
Sharp cutoff to 8 mc		
Integrated, unweighted power	3.00	4.26* db
Unweighted/weighted power, curve I	5.64	12.72
Unweighted/weighted power, curve II	4.21	9.56
Unweighted/weighted power, curve III	2.87	6.35
*Sloping cutoff to 5 mc***	*Flat*	*"Coaxial"***
Unweighted/weighted power, curve I	2.2	6.9 db

* In this distribution the watts per kilocycle have been set as equal at 4 mc to the watts per kilocycle in the flat distribution.

** See reference 1.

estimated as having an unweighted signal-to-noise ratio of 38.1 db (with synchronizing pulse 41 − db). This is flat, so that with the weighting of Fig. 2, the weighted figure would be 43.5 db. Compared with the 2P23 tube, the performance is characterized, "This gain in signal-to-noise ratio is very worth while and makes the tubes acceptable for studio application." It is understood, informally, that for good tubes the figure of 38.1 db is likely to rise to a little over 40 db.

The 5769 image orthicon (same size of photocathode image as 2P23 and 5655) is described, but no figures given on signal-to-noise ratio except the statement, "The 5655, however, is superior in its signal-to-noise ratio. . . ."

The 5820 image orthicon (same size of photocathode image as others) is described in the more recent paper of the reference, but no statement is made as to its signal-to-noise performance. It is understood, informally, that its unweighted signal-to-noise ratio is of the order of 34 db. Weighted, and with synchronizing pulse, the figure would become 40 db.

No data are given in this literature on the signal-to-noise ratio of the 5826 image orthicon (same size of photocathode image as others), but it is understood, informally, to be of the order of 37 or 38 db. Weighted, and with synchronizing pulse, this becomes 43 db.

It has been noted above, in the presentation of Fig. 1, that the dotted lines refer to the data as taken. In the tests the slide was scanned by a special test scanner, revised from a prewar scanner.[10] From general experience with this scanner, it is considered to have low though visible noise. By the addition of a constant noise, on an rss basis, to that indicated by the dotted lines, they can be straightened out, as shown by the solid lines, and it is estimated that this constant noise measures the contribution of the film scanner. The figure is shown to be 46 db signal-to-weighted noise (including synchronizing signal). If the distribution were flat, the unweighted figure, for the 4-mc band, would be 43 + db.

6. Appendix

For simple reference the results of computations of two sharp cutoff and two sloping cutoff distributions, with the

weightings shown in Fig. 2, are given in Table III.

References

1. P. Mertz, "Perception of television random noise," *Jour. SMPTE*, vol. 54, pp. 8–34, Jan. 1950.
2. M. Luckiesh and F. K. Moss, "The variation in visual acuity with fixation-distance," *J. Optical Soc. Am.*, vol. 31, pp. 594–595, Sept. 1941; *The Science of Seeing*, Van Nostrand, New York, 1937; "The dependency of visual acuity upon stimulus distance," *J. Optical Soc. Am.*, vol. 23, pp. 25–29, Jan. 1933.
   E. Freeman, "Anomalies of visual acuity in relation to stimulus-distance," *J. Optical Soc. Am.*, vol. 22, pp. 285–292, May 1932.
3. P. Mertz, A. D. Fowler and H. N. Christopher, "Quality rating of television images," *Proc. Inst. Radio Engrs.*, vol. 38, pp. 1269–1283, Nov. 1950.
4. C. E. K. Mees, *The Theory of the Photographic Process*, Macmillan, New York, 1942.
5. O. H. Schade, "Electro-optical characteristics of television systems: Introduction," *RCA Rev.*, vol. 9, no. 1, pp. 5–13, Mar. 1948.
   "Part I—Characteristics of vision and visual systems," *ibid.*, pp. 13–37, Mar. 1948.
   "Part II—Electro-optical specifications for television systems," *ibid.*, no. 2, pp. 245–286, June 1948.
   "Part III—Electro-optical characteristics of camera systems," *ibid.*, no. 3, pp. 490–530, Sept. 1948.
   "Part IV—Correlation and evaluation of electro-optical characteristics of imaging systems," *ibid.*, no. 4, pp. 653–686, Dec. 1948.
   "Image gradation, graininess and sharpness in television and motion picture systems," Part I: Image structure and transfer characteristics," *Jour. SMPTE*, vol. 56, pp. 137–177, Feb. 1951.
6. H. L. Logan, "Brightness and illumination requirements," *Jour. SMPE*, vol. 51, pp. 1–12, July 1948.
7. M. W. Baldwin, "Allocation standards for very high-frequency television and frequency modulation broadcasting," (Report of experiments of T. R. D. Collins, Annex 8) *Proc. Joint Technical Advisory Comm.*, vol. II, Dec. 1948. (This publication is available at The Joint Technical Advisory Committee, 1 East 79th St., New York 21.)
   E. W. Chapin and G. H. Brown, Exhibits 389 and 424, respectively, Dockets 8736, 8975, 9175 and 8976, "Record of FCC Hearing on Color and Allocations, 1950." (This publication is available at the Federal Communications Commission, Washington, D.C.)
8. L. A. Jones and G. C. Higgins, "Photographic granularity and graininess,
   "Part I—The relationship between the granularity and graininess of developed photographic materials," *J. Optical Soc. Am.*, vol. 35, pp. 435–457, July 1945.
   "Part II—The effects of variations in instrumental and analytical techniques," *ibid.*, vol. 36, pp. 203–227, Apr. 1946.
   "Part III—Some characteristics of the visual system of importance in the evaluation of graininess and granularity," *ibid.*, vol. 37, pp. 217–263, Apr. 1947.
   "Part IV—Visual acuity thresholds; dynamic versus static assumptions," *ibid.*, vol. 38, pp. 398–405, Apr. 1948.
   "Part V—A variable-magnification instrument for measuring graininess," *ibid.*, vol. 41, pp. 41–52, Jan. 1951.
   "Part VI—Performance characteristics of the variable-magnification graininess instrument," *ibid.*, vol. 41, pp. 64–75, Feb. 1951.
   "Part VII—A microphotometer for the measurement of granularity," *ibid.*, vol. 41, pp. 192–200, Mar. 1951.
9. R. B. Janes, R. E. Johnson and R. S. Moore, "Development and performance of television camera tubes," *RCA Rev.*, vol. 10, pp. 191–223, June 1949; R. B. Janes, R. E. Johnson and R. R. Handel, "A new image orthicon," *ibid.*, vol. 10, pp. 586–592, Dec. 1949.
10. A. G. Jensen, "Film scanner for use in television transmission tests," *Proc. Inst. Radio Engrs.*, vol. 29, pp. 243–249, May 1941.

Modified Negative Perforation

Proposed as a Single Standard for 35-Mm Negative and Positive Motion Picture Film

By W. G. HILL

The existence of two or more perforation shapes for 35-mm films has, for many years, been considered undesirable. For processes requiring accurate film positioning, the dual Standard of Negative perforation for camera stock and Positive perforation for release stock does not suffice. Registration problems are minimized if Negative perforations are used throughout; experience, however, has shown that projection life is short. The Modified Negative perforation, with fillets at the corners, has improved resistance to tear while preserving the general negative form corresponding to conventional piloting means. Tests conducted show that better film positioning is accomplished in conventional camera and printing equipment for film with Modified Negative perforations than for film with Dubray-Howell perforations. The method of evaluating film location during exposure and printing is described and evidence of results presented. Photoelectrically recorded charts show the extent of out-of-register which resulted for various combinations of perforation types. Film-life projection tests indicate that the Modified Negative perforation is equal or superior to the Dubray-Howell perforation.

The perforated holes in motion picture film provide a means whereby the continuous strip material can be propelled in synchronism with and in register to various machine components used in the production and reproduction of successive picture images. For the most part, sprocket wheels and pilot pins are used to engage the film perforations and effect positioning of the film strip. The former are most extensively used in printing and projection equipment whereas pilot-pin devices are more common in cameras and step printers where the advance of the film is intermittent and extreme accuracy is required. For many processes, such as in color film work, consistently accurate positioning of the film is of utmost importance. This is particularly true when more than one negative film is used to make up the master, and is desirable in all reproduction processes in order to preserve screen steadiness. The fit of the perforations on the registration sprocket teeth or pilot pins influences the degree of steadiness

A paper presented on May 2, 1951, at the Society's Convention in New York, by W. G. Hill, Ansco Division, General Aniline & Film Corp., Binghamton, N.Y.

in the final release print and is, therefore, of vital concern to the motion picture industry.

The general form of the Standard Negative perforation, modified to the extent of incorporating slight fillets at the corners, is a shape of perforation worth considering as a single standard for 35-mm film. Experience with the negative form and tests conducted on film with the suggested modified perforations show this curved-end type of hole to be suitable for camera, dupe and release films. Image registration and picture steadiness, as produced with typical equipment, are improved when using the Modified Negative perforations noted above over that accomplished with the use of the present Negative and Positive combination or proposed rectangular Dubray-Howell perforation. Tearing of the film at the perforation during projection is less severe for the Modified Negative perforations than for the Dubray-Howell perforations tested. It appears that advantages gained by adopting the Modified Negative perforation as a single standard can be realized without the necessity of altering equipment.

Perforation Shape

Considerable information dealing primarily with the size and shape of the hole has been published on the standardization of perforations for 35-mm films. The history and reference to papers on the subject are well covered in a *Journal* report.[1] The proposal embodied in the report and presented for trial and comment specifies a rectangular perforation 0.110 in. × 0.073 in. with 0.013-in. corner fillets. This form of perforation was proposed by Dubray and Howell in 1932 and is usually referred to as the Dubray-Howell perforation. With recent acceptance of this perforation by some processing companies, we now face the problem of dealing with three types of perforations instead of two, which the industry has accepted as standards for many years. The Dubray-Howell perforation is substantially the same shape as the Standard Positive, but has a height of 0.073 in. instead of 0.078 in. and corner radii of 0.013 in. as against 0.020 in. for the Positive. The 0.073-in. dimension (same as for the Standard Negative perforation) is calculated to give no new difficulties in sprocket-tooth-to-film interferences. More important is the fact that there are advantages in the overall perforation size being the same for all camera, dupe and printing stocks. It is believed that with the new low-shrink safety film supports there is no valid reason to continue using the oversize Positive perforation. Experience has shown that the smaller perforations of like size and shape can be successfully used for all general types of 35-mm film. Since most commercial film-handling equipment, precision built to provide accurate registration, is designed to fit the Standard Negative perforation, Z22.34, it appears advisable to maintain the overall size therein specified for negative raw stock rather than the larger positive size.

The circular-end form, like the Negative standard which has been almost universally used since 1918, gained wide acceptance and is still used for work requiring accurate registration. Although efforts have been made in this country and Europe to standardize on the rectangular Positive perforation, and more recently in this country to standardize on the Dubray-Howell perforation, the round-ended perforation has, nevertheless, survived. Reluctance to accept the Dubray-Howell type of perforation as a single standard may be explained partially by the fact that new pins and sprockets to correspond are necessary in order to gain the most benefits in improved registration. In this connection, it should be noted that in the report of the Subcommittee on Perforation Standards, published in the *Journal*,[2] reference is made to proposed new pilot pins and sprocket teeth to fit the Dubray-Howell perforation for improved means of regis-

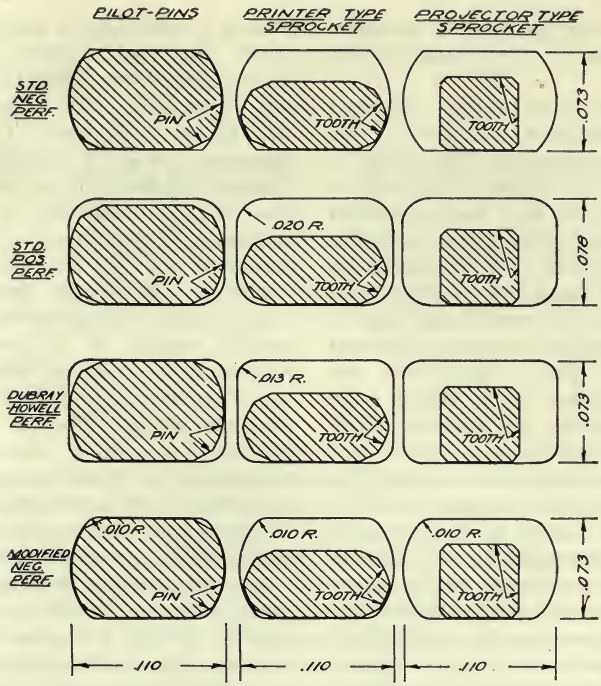


Fig. 1. Relationship of various perforations to pilot pins and sprocket teeth.

tration. In regard to printer sprockets, the report points out that, "...the recommended modification of printer sprocket design would be a marked improvement in the printing process, but would not be essential." Further, the report states, "It is to be noted, however, that locating on the unmodified printer sprocket two films having rectangular perforations requires some care." Stock films with Negative perforation could not, of course, be accommodated on rectangular teeth of the proposed modified sprocket. Because of such complications and additional expense of changeovers, the rectangular perforation form has not been accepted by the industry as the single standard for negative and positive films. The negative Bell & Howell perforation without corner fillets, although proven by experience to register accurately on existing equipment and provide adequate steadiness, is not ideally suited for projection films because of its low resistance to tear. The solution seems to be the establishment of a single universal perforation which will give good registrations on present piloting pins and sprockets and at the same time have sufficient strength so as not to limit projection life. Further, such a perforation should, when used for positive and negative film or in conjunction with "stock" film having Standard Negative perforations, register with the best possible accuracy without the necessity of altering equipment. The author believes that a modified form of the Standard Negative perforation, discussed in this paper, meets these requirements and makes possible the unlimited use of form-fitting sprockets for side guiding.

Figure 1 shows four types of perforations under consideration and the rela-

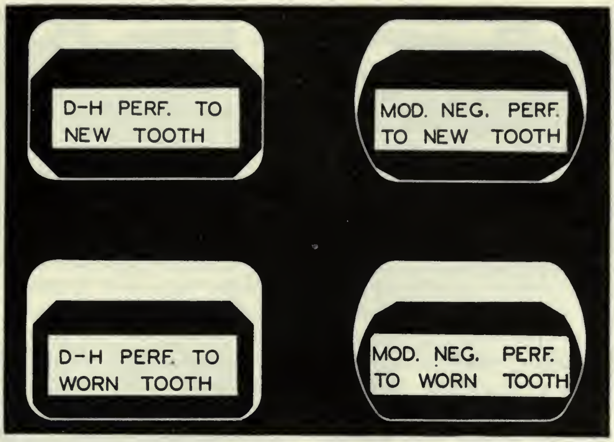


Fig. 2. Drawing showing side clearance between perforation and guiding sprocket.

tion each may assume with respect to commonly used pins and sprocket teeth. The curved-end form, Negative and Modified Negative, the latter differing from the Standard Negative only in the 0.010-in. fillet at the corners, are substantially full fitting with the pilot pins. In contrast to this, the rectangular Dubray-Howell and Positive perforations locate at the ends by point contact only. The Positive hole, being 0.005 in. higher than the pin thickness, does not, of course, fit along both long sides as do the other three holes. As for the relation with typical printer sprocket teeth, the round-ended forms locate sidewise at the driving tooth, whereas clearance exists at the short sides of the Dubray-Howell and Positive holes. In the case of the projector sprocket and those used where registration is not critical, the relation of perforation to tooth is similar for all types shown. The fit of perforations to the registering sprocket tooth as shown for printers suggests that the same tooth form could be used in projectors and related equipment where better steadiness is desirable. Note that the round-ended form of hole, with tooth to correspond, provides what appears to be a more reliable self-centering means. If wear on the sprocket tooth is considered, it is evident that the round-ended form is superior in that, as the face and the side of the tooth wear, the Negative form tends to wedge and center the perforation. The rectangular tooth, when worn, is not self-compensating and clearance at the sides will result. This is shown schematically in Fig. 2. Wear on the sides of the rectangular form results in clearance between tooth and perforation and destroys the ability of the tooth to register the film properly. A similar condition may result for pilot-pin registration. Guiding the film by full-fitting pins or teeth at one row of perforations is common practice where positioning of the film is critical. But where side motion need not be closely controlled, the teeth are narrower than the perforation width. In this case, shoulder edge guides are usually used and for such applications the perforation shape does not pose a problem. As for affecting accurate transverse registration by forcing the film against one side of the tooth, those familiar with film-handling equipment recognize the potential difficulties.

It appears evident, therefore, that the adoption of the suggested Modified Negative perforation should be given

consideration. Little, if any, reluctance to accepting such a perforation is expected if field trials bear out our finding as determined by factory tests. A single-perforation type would permit reduction of tool expense and inventories for the film manufacturers, and would permit greater flexibility in machine usage. The expense of changing to the specific Modified Negative form suggested would be no greater than for the Dubray-Howell. In fact, when considering the possible necessity of changing equipment which is now designed to register Standard Negative perforations, the expense for the change to Dubray-Howell would be greater. For the studio and laboratory, no extra expense or new problems should arise by the acceptance of the Modified Negative perforation. There would be no need to provide two types of pins or heads. With all new films supplied with Modified Negative perforations, the registration problem, particularly if stock negatives must be used, is simplified. For the film distributors and theaters, the Modified Negative perforation should give sufficient resistance to tear at the perforation area. Indications are that the Modified Negative hole weakens the film less than the Standard Negative and is equal to or better than the Dubray-Howell.

Briefly, the Modified Negative type of perforation has several advantages over the Dubray-Howell form. The most outstanding, perhaps, is the improvement gained in registration on standard continuous printers which are used extensively for making final release prints. Also important is the fact that existing perforated film could be run on any equipment made to conform specifically to the Modified Negative perforation.

The discussion to follow describes actual tests with camera and printing films having various types of perforations. The method of evaluating "unsteadiness" is indicated and evidence of the results presented in the form of recorded charts. Tear studies comparing the Dubray-Howell and the Modified Negative perforation are also described.

Test Method—Film Registration

The term registration, when used in connection with motion picture-making processes, generally implies the positioning of one film with respect to others or with respect to some fixed part of the equipment. Film exposed in the camera is piloted by pins engaging the perforations so that the film is oriented similarly for each successive frame and accurately positioned. Print registration is accomplished by piloting the picture negative and the duplicating stock accurately frame by frame or perforation by perforation, so the image transfer is "in-register." Any out-of-register contributes to picture unsteadiness and, for processes requiring multiple exposures, causes poor image definition.

The perforated holes are punched in the film by tools made to extremely close tolerances. These holes serve as a reference point to which image position is gaged. The degree of improper registration and variations in film positioning, therefore, can be determined by measuring the distances from the perforations to a point in the photographic image. The process of frame-by-frame measuring of these distances under the microscope is laborious and, consequently, is usually limited to comparatively short samples. To check the practical significance of such findings, it is desirable to examine longer lengths of film and correlate the data with results as found by a jury viewing the projected picture. The method of evaluating steadiness used by Ansco in the studies described here permits visual examination of the projected image and, at the same time, records the extent of image shift attributed to improper piloting of the film at the time of exposure. Long lengths of film can thereby be tested and data obtained without the need of the time-consuming frame-by-frame measurements. The sys-

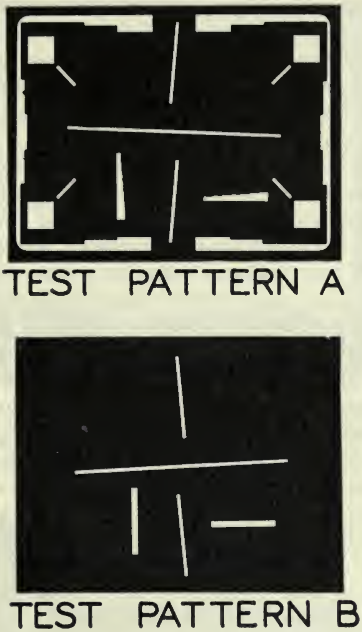


Fig. 3. Target patterns.

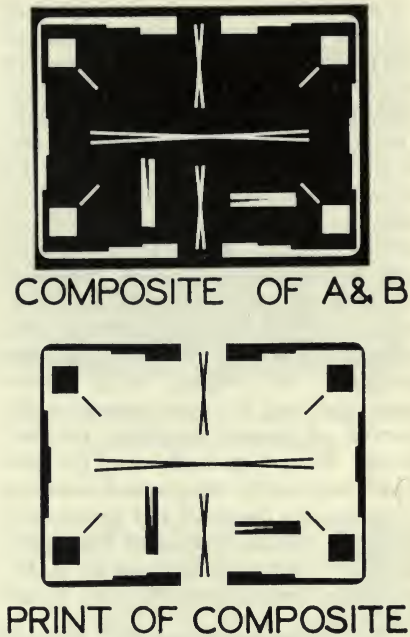


Fig. 4. Composite of target patterns.

tem of using double-exposed images to indicate out-of-register, which is familiar to some, was selected not only to enable convenient viewing by projection but also to permit the use of a single-channel recording device.

Two "targets," illustrated in Fig. 3, were provided in order that exposure, first to one and then to the other, would result in cross-line patterns and also form "light slits," the sizes of which vary depending on the differences in positioning of the film during the first and second exposure. The crossover lines, forming tapered wedges, are used primarily for visual studies of the projected image, whereas the stepped slits are arranged conveniently for photoelectric recording of the vertical and horizontal variations. Figure 4 represents the composite formed by superimposing image of target A and target B, shown in Fig. 3. The size of the original target was selected so as to give successive step distances of 0.002 in. on the wedge image formed on the camera film. This provided a means of visual checking of the approximate variations in "slit" width on the printed film during projection. The system of superimposing images described is applicable not only to testing registration ability of equipment for a particular film, but valuable, as in this case, in evaluating different films or types of perforation holes on given equipment. In the latter case, the same camera, printer and related apparatus were used for all comparison tests, thereby eliminating variables in equipment. It is well to point out that in testing for registration, by the method of superimposing films, the maximum shift of the first to second images may be twice that for either image separately. This total shift of one with respect to the other, however, is what may be encountered in actual picture making and consequently is indicative of the true situation.

For purposes of investigation, 300 ft of each test film were exposed in a camera; 100 ft to target A; the second 100 ft to target B; and the third 100 ft, consecutively superimposed to targets A and B. The latter, composite negative of A and B, was used to check registration in the camera. For the print tests, a 100-ft dupe film was printed from camera negative of target A and then "in-register" with the negative of target B. Prints of the resulting picture composites (illustrated in Fig. 4) were projected and image registration of the various samples compared. In judging image movement, that due to out-of-register in the camera, of course, was taken into account. Picture unsteadiness of the projected step-wedge images was recorded by means of a photocell and appropriate electrical circuits, a detailed description of which is given in the paper by R. W. Lavender, immediately following in this Journal.

Test Apparatus and Equipment

Photographic apparatus used in the testing program was standard commercial equipment, typical of that in general use by the trade. No attempt was made to replace critical parts of the equipment which might have been worn by normal use. On the contrary, equipment used for routine trials was selected as being equivalent to that in operation in many studios and laboratories. Pilot pins and registering sprockets were the Standard Negative type. Most of the trials were made at the Ansco factory; however, some runs were conducted at other plants. Although it is recognized that the introduction of a new perforation standard would affect operations on a number of different machines including special-effects projectors, splicers, recorders, etc., it was deemed sufficient to limit the tests to typical cameras, continuous printers, step-optical printers and theater projectors. Film advance and registration mechanisms contained in such units represent, in general, the types of movements universally used. Therefore, evaluation of steadiness and performance for the test described here was limited to trials on the four types of equipment noted.

A Mitchell camera having synchronous motor drive and Standard Negative pulldown and pilot pins was used. The Bell & Howell model continuous printer, used for making evaluation prints, had Negative-type sprocket teeth for effecting side guiding of Standard Negative perforations. Step-optical prints were run on an Acme-Dunn unit which is maintained by our Motion Picture Development Department for testing purposes. Projection runs were made on a Super Simplex with a 0.935-in. diam, 16-tooth, intermittent sprocket. The 50-amp arc light was used during wear and tear tests. For steadiness evaluation trials, however, the light was converted to a 2100-w, 60-v incandescent lamp. This light source provided constant illumination which is essential to the system used for recording.

Figures 5A, 5B and 5C show the test screen and equipment setup for recording steadiness data. View 5A is of the projection side of the screen on which is mounted two photocells and the calibrating unit. The photocells are arranged so the projected image of the step-wedge formed on the film by the double-exposed target pattern falls on the light-sensitive cell element. View 5B is of the calibrating device. This is simply a d-c motor which drives an eccentric bushing mounted to form a rectangular window with a second bushing and the top and bottom of the opening in the cell housing. Both bushings are made to push-fit over the shafts in order that different diameters and eccentrics may be used to vary the slot width. Figure 5C shows the amplifier and recording equipment mounted at the rear of the screen. The test screen was positioned so as to give a 50× enlargement of the projected image at the screen.

Fig. 5A. Test screen from projector side, showing photocell holders and calibrating unit.

Fig. 5B. Close-up of calibrating unit mounted in front of photoecll.

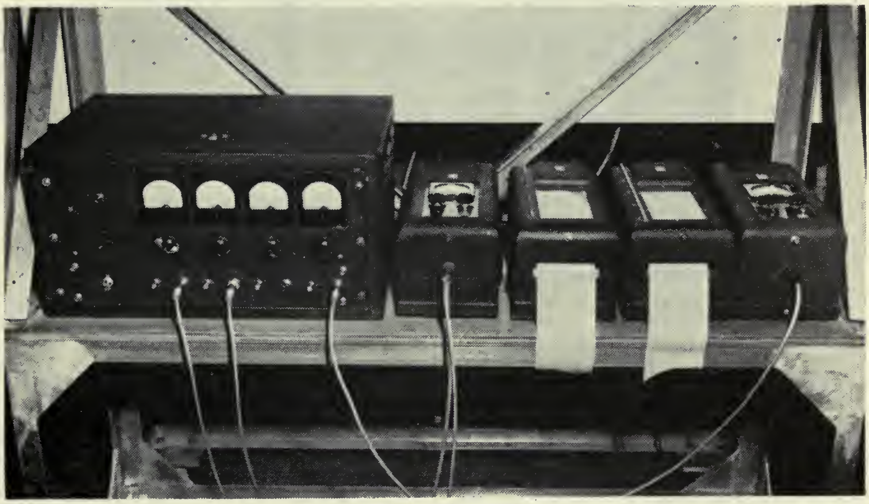


Fig. 5C. Electronic units and recorder mounted at rear of screen.

Registration Studies

Each test series, including samples of various perforations under consideration, was conducted on material from the same film coating and, where possible, was selected from the same 35-mm roll. For the most part, testing was limited to safety base materials typical of those now used in motion picture work. Some steadiness checks, however, were made on nitrate base but no attempt was made to draw comparisons between performance of the two materials. Dubray-Howell and Modified Negative tools, used in perforating the sample films for test X, were made to like tolerances and se ected to give comparable hole sizes. All runs in a given series were made consecutively under similar conditions so as to eliminate variables which might reflect

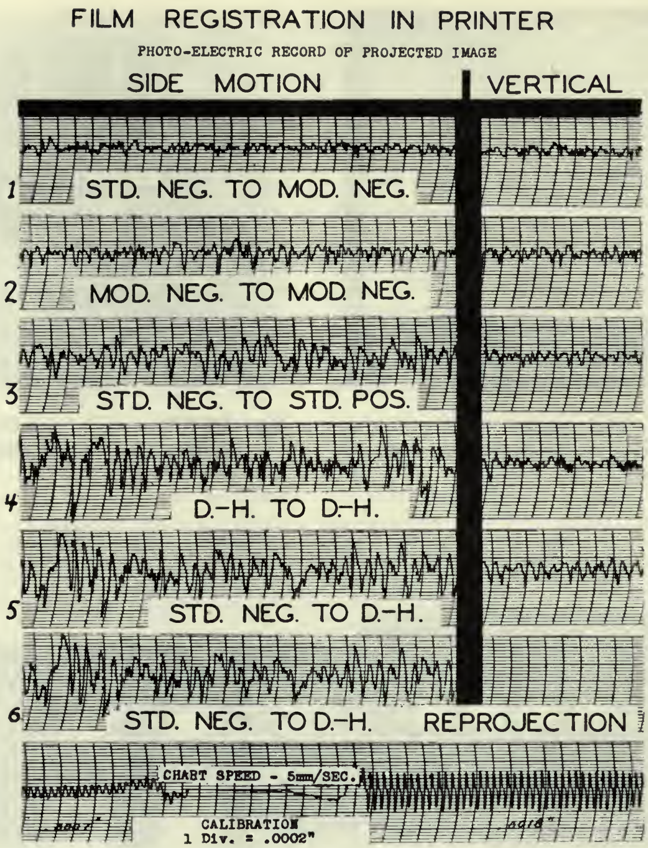


Fig. 6. Charts—Test X on sprocket printer.

in the data and thereby render the comparisons questionable.

The steadiness or degree of film registration accomplished on a Bell & Howell continuous printer, test X, is indicated in Fig. 6. These charts are the results of photoelectrical detection of the relative shift of first- and second-exposure images as observed during projection of the printed test film. The pattern, forming light slits at which the variations were measured, was the result of printing the negative of target A to the positive film and then printing the negative of target B to the same positive film. Therefore, variations or out-of-register shown are those due to nonuniform positioning of the films on the printing sprocket and inaccuracies in the original negatives. The latter are comparatively small as will be shown later in Fig. 8. Film having Standard Negative perforations was double printed to films with Modified Negative, Standard Positive and Dubray-Howell perforation. The recorded out-of-register results are shown by charts 1, 3 and 5 of Fig. 6. In the case of chart 1, Standard Negative to Modified Negative, the average side motion was approximately 0.0007 in. For chart 3, to Standard Positive, the variation is in the order of 3 times that

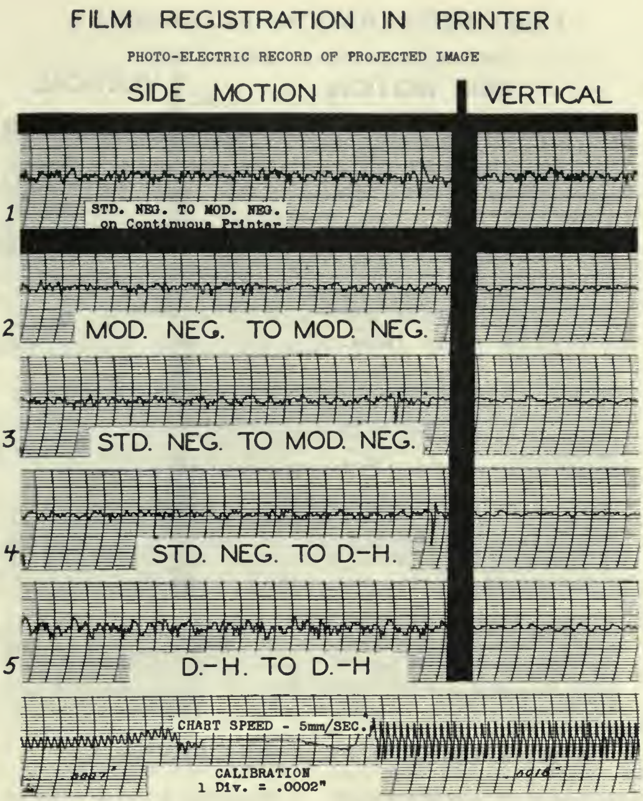


Fig. 7. Charts—Test X on optical printer.

for chart 1, and for chart 5, to Dubray-Howell, about 4 times. The results of printing camera negatives, having Modified Negative holes, to films with the same type of perforations, and negatives with Dubray-Howell holes to like film, are shown by charts 2 and 4, Fig. 6. Variations for the Modified Negative perforation appear to be distinctly less than for the Dubray-Howell combination. In order to verify the accuracy of recording out-of-register, the test print was reprojected and the results compared with the previous run. One section of the chart thus obtained is shown in curve 6 of Fig. 6. In comparing this with curve 5, it will be noted that the duplication is near perfect. Vertical motion between the first and second printed images shown at the right of Fig. 6 appears to be comparable for all samples (about 0.0010 in.). The calibration chart at the bottom of Fig. 6 was obtained by projecting the clear area of the test film through the controlled variable calibrating slot and onto the photocell. Knowing the magnification and slot-width change at the cell, the gain of the unit was set so that each small division on the chart represented approximately 0.0002 in. at the film. With the slot area fixed, and the cell receiving light through the clear film area, no movement of the recorder pen could be detected; thus indicating that the variations in light intensity and film density were negligible.

The same camera negatives used for the continuous printer test described

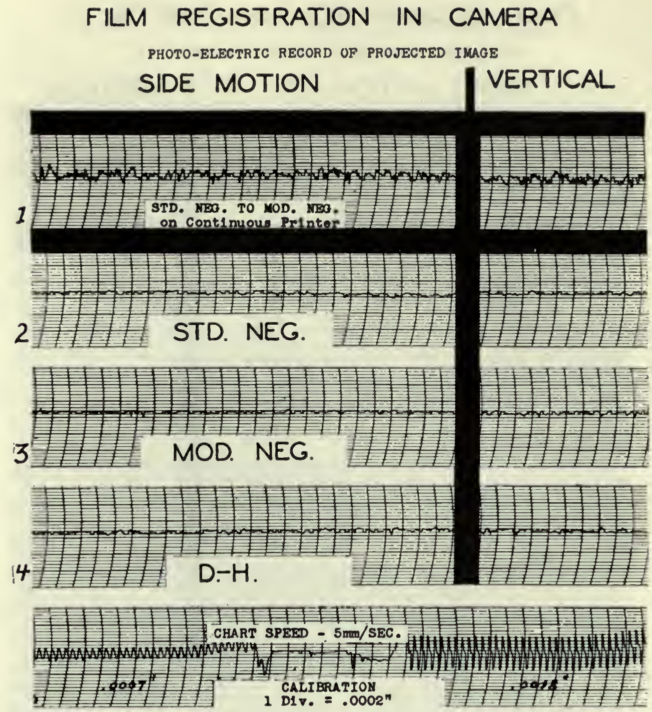


Fig. 8. Charts—Test X on intermittent camera.

above were also used for testing out-of-register on a step-optical printer. Using the same general method as before, the charts shown in Fig. 7 were recorded. Charts 2, 3 and 4 for Negative-type perforations on originals to Negative and Dubray-Howell types are comparable, indicating side motion of from 0.0006 to 0.0008 in. These also show side motion to be in the same order of magnitude as on chart 1 for the continuous print sample of Standard Negative to Modified Negative perforations. The print of Dubray-Howell to Dubray-Howell, chart 5, shows greater side movement, from 0.0010 to 0.0012 in. Vertical motion for all step-optical prints was about the same (0.0004 in.). The degree of vertical unsteadiness in these instances was much better than for the continuous prints and only slightly worse than for the camera test.

Charts 2, 3 and 4 in Fig. 8 are records of variations attributed to inaccuracies in positioning of the film in the camera. All samples show from 0.0003-in. to 0.0004-in. variations in the horizontal and vertical direction. Chart 1 (Standard Negative to Modified Negative) of the continuous print sample of least variation (0.0007 in. avg.) serves as a comparison to the camera registration performance curves.

Test Y, Fig. 9, charts 1, 2 and 3 are taken from a different series of camera and print film tests. The negative, which was perforated with tools converted from Standard Negative to Modified Negative type, was exposed by Ansco to test targets as previously described, but the printing was done by a commercial laboratory. These trials served not only to verify earlier observations but to check the degree of correct registration

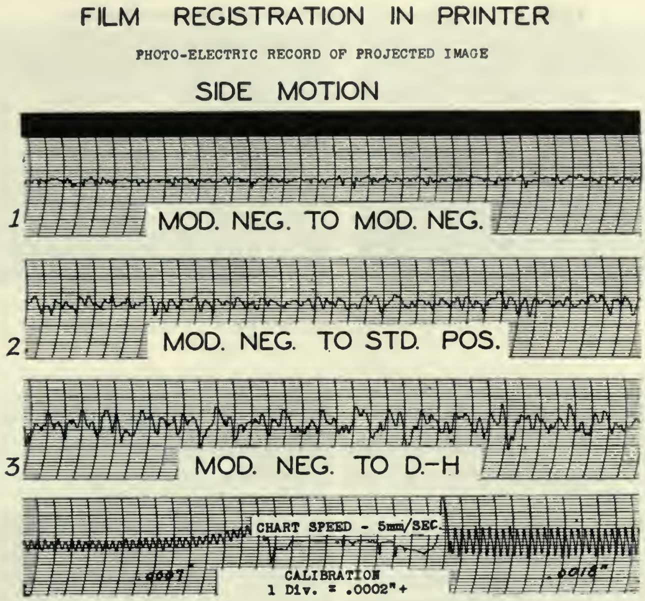


Fig. 9. Charts—Test Y on sprocket printer.

which might be expected when printing from the new Modified Negative perforated stock onto stock with the same perforations and also onto release or dupe film with Positive or Dubray-Howell perforations. The results of this laboratory test show the Modified to Modified to be best, variations being in the order of 0.0006 in. For the Modified to Dubray-Howell, however, variations were about three times greater. It will be noted that the calibration amplitude shown by the lower chart in Fig. 9 is slightly less than for the other figures, the smallest scale division equaling 0.0002 in. plus, or a little greater than for the other figures. This change may be accounted for by difference in density of the film used for the two series.

In reviewing steadiness tests conducted at Ansco over a period of several months, it is evident that in each case, the curved-end style of Negative or Modified Negative perforation is superior. This form of perforation hole gave the best steadiness when used for both the camera and print films. Negatives printed to film with rectangular perforation were not as good; however, they were distinctly better than for the Dubray-Howell type perforated camera material printed on Dubray-Howell perforated release stock. Our findings substantiate the theory that improved pin registration and sprocket guiding will result on commonly used commercial equipment if film with curved-end perforation is used throughout.

Perforation Wear and Tear Resistance

Film samples for wear tests were made up in 40-ft loops. Although some trials were made on loops containing only one type of perforation, the data presented here is a comparison of two types of holes in the same film strip. Both tests reported here were on safety film, developed clear and projected on the same machine. Films for wear tests were not waxed or otherwise conditioned to improve projection life as is usually done commercially. In preparing film strips,

Table I. Number of Torn Perforations per Frame

Film D-145-1: Loop 1			Film D-145-2: Loop 2		
No. of Projections	Mod. Neg. Perf.	D-H Perf.	No. of Projections	Mod. Neg. Perf.	D-H Perf.
202	2(slight)	3(slight)	220	0	1(1 slight)
396	2(1 slight)	4(2 slight)	321	0	1
508	3	5(1 severe)	715	3(2 slight)	2(1 slight)
671	3	5	974	3	5
892	3	5	1154	3	6(4 slight)
1198	3	6	1271	3	6(2 slight)
1273	5	6(4 severe)	1628	6(1 slight)	6(4 severe)
			1819	6(3 severe)	6
			1914	6	6

half of each length was perforated on a machine with Dubray-Howell type tools and without cutting the sample, the second half was perforated on a machine with Modified Negative type tools. Films were ink-frame marked for convenience in identifying perforation during the projection run. While wear tests were in progress, observations of the projected perforation area were made and the condition of tearing around the perforations noted.

Film loops were run on a Super Simplex projector No. 41180, with 50-amp arc light and equipped with a 16-tooth, 0.935-in. diameter intermittent sprocket. Table I shows the observed results of these projection wear and tear tests on two different types of safety base film.

These and similar tests indicate that,

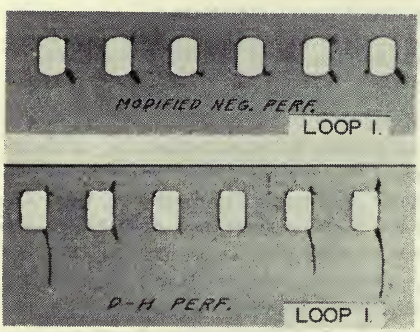
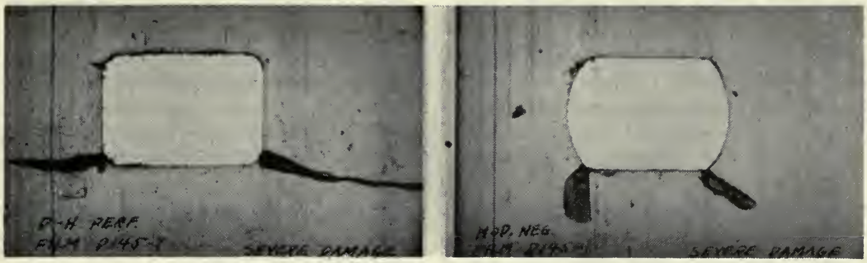


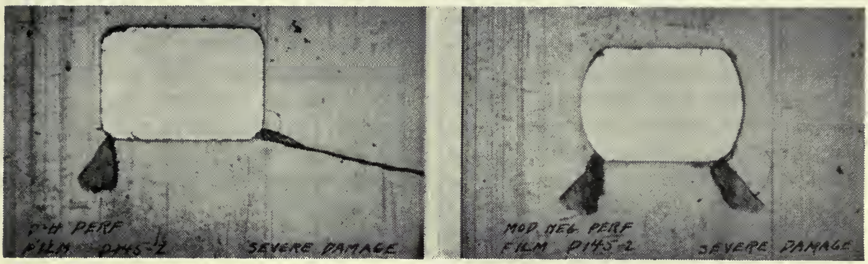
Fig. 10. View of perforation area showing projection damage to film.

under normal projection conditions, the Modified Negative form of perforation weakens the film less than does the Dubray-Howell form.

A study of the types of failure appearing at the perforation area revealed a distinct difference in the cracks which were produced during the projection runs. Figure 10 shows views of the perforation area along one side of the Modified Negative and Dubray-Howell perforated samples taken at the completion of the wear test. It will be noted that for the Dubray-Howell type the crack is sharp and progresses transversely. The tear at the corners of the Modified Negative hole is broad and more in a line forming an angle with the straight side of the hole, that is, more lengthwise of the film. These breaks at the corners of the Modified Negative do not extend into the aperture area or to the film edge, as do some of the breaks in the sample perforated with Dubray-Howell holes. Figure 11 shows enlarged photographs of perforation area from loops 1 and 2 after completion of wear test runs. Damage to the Dubray-Howell perforated sample appears to be more severe. In tests conducted for the purpose of comparing the Standard Negative with Modified and Dubray-Howell perforations, the pattern of cracks was similar to that shown in Fig. 10. Although many of the cracks on the Standard Negative perforated film were



Loop 1. Film through projector 1273 times.



Loop 2. Film through projector 1914 times.

Fig. 11. Photographs of Dubray-Howell and Modified Negative perforations at completion of projection wear test.

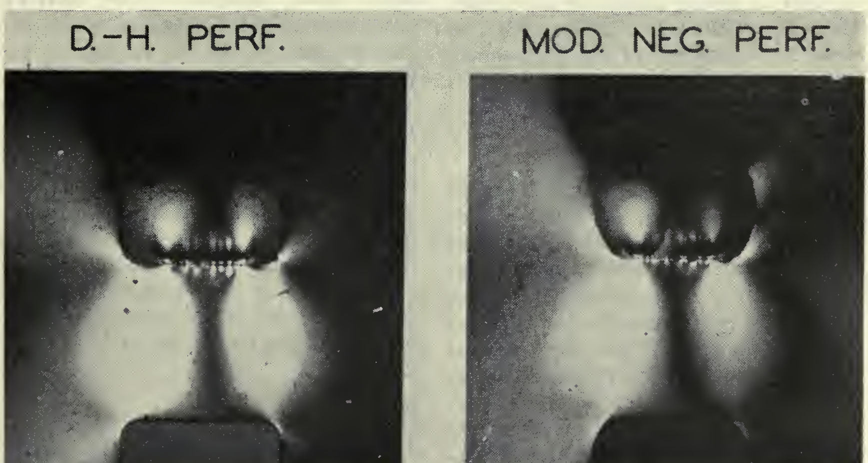


Fig. 12. Photographs of strain pattern produced by 650-g load on perforation edge.

like those shown for the Modified Negative, some cracks extended transversley much like those on the Dubray-Howell perforated sample. These long fractures which apparently progress across the film with repeated loading seem to account for the more rapid breakdown.

In an attempt to determine why the two different styles of perforations cause film under load to break differently, as shown in Fig. 11, strain pattern studies were made. Clear safety-base film samples, 0.009 in. thick, were supported at the perforation edge on a pin 0.070 in. wide with 0.010-in. corner radii and loads of increasing amounts applied to the film. By means of polarized light, strain patterns were observed. Photographs of such patterns are shown in Fig. 12. Strain areas, indicated by light sections, are more sharply defined for the Dubray-Howell type hole, the areas of strain to no strain for the Modified Negative being blended more gradually. The strain area for the Modified Negative sample extends from the corner along the curved end for some distance and then gradually falls off; whereas for the Dubray-Howell shape, the strain disappears rather sharply and is not distributed as evenly along the short side. This, it is believed, explains why the break at the corner of the rectangular hole progresses across the film and is more extensive.

Conclusions

The curved-end style of the Standard Negative perforation, now almost exclusively used for camera films, registered more accurately in the camera, step-optical printer and continuous printer than did the rectangular form of Dubray-Howell or Standard Positive perforations. The Modified Negative perforation with 0.010-in. corner radii compared favorably to the Standard Negative perforation in registration and steadiness performance, reduced the tendency of the film to tear, and caused no apparent interference with piloting pins or sprocket teeth. Film with the Modified Negative form of hole can be used without limitation on equipment designed to run the present ASA Standard Negative and Positive perforation types and will position accurately on their registering mechanisms. Image steadiness of release prints, exposed on the Bell & Howell type continuous printer, is improved by using the Modified Negative perforation throughout.

We believe the consensus favors a single standard and that the complex situation due to the existence of multiple standards should not be permitted to continue indefinitely. On the basis of theoretical considerations and tests conducted on the Modified Negative perforation, the adoption of such a perforation seems to be a practical solution and a step toward the establishment of a single standard.

Acknowledgment

The problem of judging relative performance of films with different-shape perforation holes is a delicate one. Through the efforts of several people, much information, which is invaluable in determining a satisfactory solution, has been made available. The SMPTE Film Dimensions Committee under the chairmanship of Dr. E. K. Carver has played an important part in encouraging such investigations as might lead to a final settlement and perhaps to the establishment of a single universal perforation standard. The author wishes to acknowledge the work of Carl L. Schaefer on the steadiness problem and his cosponsoring of the Modified Negative perforation as a possible universal standard. The photoelectronic recorder was developed by Raymond W. Lavender.

References

1. Proposed American Standard, *Jour. SMPE*, vol. 52, pp. 447–452, Apr. 1949.
2. Report of the Subcommittee on Perforation Standards. *Jour. SMPE*, vol. 29, pp. 376–387, Oct. 1937.

Discussion

L. L. Ryder: How do you distinguish between lack of registration from perforation deficiencies and the other factors that contribute to lack of registration?

Mr. Lavender: The method described, will distinguish only steadiness components relative to the screen or relative to the perforations. Whether unsteadiness is due to perforation defects or design, or whether it is due to something within the projector, the camera or the printer, is something which has to be determined by other means.

Mr. Ryder: The data was used to determine the more essential system of perforating. Could that not also be partly attributed to the care of perforating, or the accuracy of perforating, rather than the type of perforation?

Mr. Hill: There is no question that the accuracy of perforating definitely has a bearing on results. We were primarily comparing one film with another, and therefore in perforating these films we took care to see that the tools and machines were as nearly alike as possible. The punches and pilots were made to the same tolerances and, therefore, we feel that it is a fair comparison of types of perforation. I might add that you could locate photocells at various positions, perhaps on two successive perforations, or at the first and third on a frame, and, by the method Mr. Lavender has explained, get variations in perforation pitch and alignment.

Photoelectronic Method for Evaluating Steadiness of Motion Picture Film Images

By R. W. LAVENDER

Comparative data on the steadiness of motion picture film images are generally obtained by recording the qualitative observations of viewers. Recent problems encountered in evaluating the relative merits of several types of perforations, each of which was being considered as a universal 35-mm standard, necessitated the development of a method for obtaining specific quantitative steadiness data. An instrument which utilizes variable-area photoelectric recording techniques was devised to measure, indicate and record steadiness data of the motion picture image relative to the screen and/or perforation. Use of this instrument and a special test screen permits viewing of a projected motion picture test film while simultaneously measuring the image steadiness and recording the data measured.

The steadiness of a motion picture depends on the accuracy with which successive projected picture frames occupy the same position on the viewing screen. The positional variations of the frame image relative to the screen can be completely defined in terms of any one or combination of the following:

(a) longitudinal position variation, Fig. 1a;

(b) transverse position variation, Fig. 1b; and

(c) rotational position variation, Fig. 1c.

Although steadiness, as defined above, is a quantitative measurement of the positional variation of the motion picture frame image relative to the viewing screen, it is the subjective or apparent steadiness which is generally of primary importance. Thus, the present visual test method of evaluating steadiness by jury opinion is fundamental. Nevertheless, specific quantitative data are frequently desired for the purpose of more accurately determining the magnitude, frequency, and source or sources of unsteadiness. For example, recently it was considered desirable to obtain quantitative steadiness data of film which had been perforated with several different types of perforations, namely, the Dubray-Howell, the Standard Negative and the Modified Negative—the latter proposed by W. G. Hill and C. L. Schaefer of Ansco. Each of the foregoing perforations was being considered as a universal 35-mm standard.

In an effort to obtain basic comparative data on the relative steadiness of the above perforations, the photoelectronic recorder described herein was developed.

Presented on May 2, 1951, at the Society's Convention at New York, by R. W. Lavender, Ansco Division, General Aniline & Film Corp., Binghamton, N.Y.

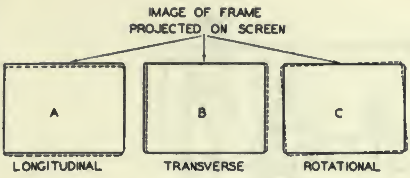


Fig. 1. Steadiness components of motion picture frame image.

The results of tests conducted with this instrument relative to perforation steadiness plus others are described in W. G. Hill's paper, "Modified Negative Perforations Proposed as a Single Standard for 35-Mm Motion Picture Film" (the paper immediately preceding in this JOURNAL).

The subject recorder, in addition to being of some value as an adjunct to the visual test method of steadiness evaluation, has a further usefulness in that it can provide recorded data which will indicate the amount of unsteadiness contributed by the camera and printer and/or projector. Further, these data are obtained concurrently with the visual inspection. If desired, the observer of the projected image on the screen may operate switches which will cause identifying marking "pips" to be made on the recorded chart for reference purposes.

The instrument is basically a variable-area photoelectronic recorder in which movement of the projected frame or image, relative to the viewing screen, results in a change in the total light flux falling on one or more photocells. This is illustrated in Fig. 2, which shows the photocells mounted on the test screen on which is projected an image of the film including the perforations—the gate of the projector having been opened to permit the projection of the full film width. Note that a longitudinal displacement of the picture frame, frame image and perforation image, results in a vertical movement of the position of the boundary line between the cross-hatched and clear areas relative to the photocells.

If the following assumptions are made:

(a) the cross-hatched area, Fig. 2, is opaque and the clear area transparent;

(b) the light intensity is constant and is uniformly distributed over the photocell window area; and

(c) the sensitivity of the cathode surface of the photocell is approximately constant over the area chosen;

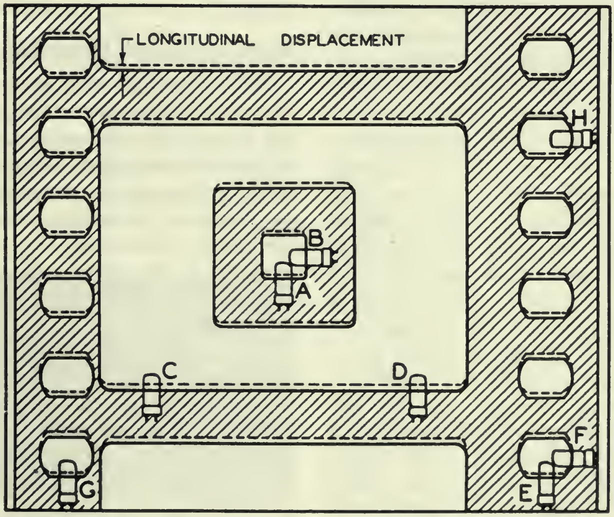


Fig. 2. Positions of photocells on test screen.

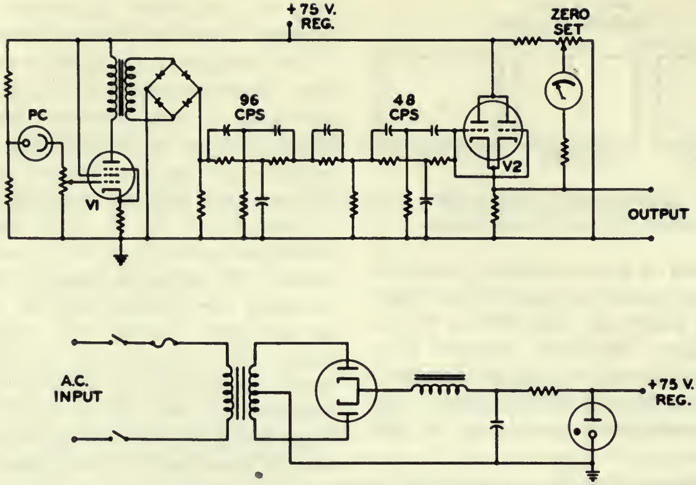


Fig. 3. Photocell demodulator channel—elementary.

then the position variations of the boundary between the cross-hatched and clear areas relative to the photocell windows will result in proportional changes in photocell output current.

It is desirable and necessary that the constant of proportionality, for boundary position variations to output current or voltage change, should have the same value for each photocell. When this is the case, the output may be calibrated in terms of position, and the output data obtained from any one photocell may be directly compared with that from any other. In other words, a specific position displacement of the boundary between the clear and opaque areas, parallel to any photocell, e.g., 1 in., will result in a current or voltage output change of one volt from any photocell. The above is practically accomplished by making the window in each photocell enclosure, Fig. 5, the same physical size and shape, and providing means in an external circuit whereby the maximum photocell output voltage may be adjusted when the photocell window is fully within the clear area. More specific details on the actual circuit adjustments necessary to satisfy the assumed conditions are given under the heading *Instrument Adjustment and Operation,* below.

In the practical application of the proposed photoelectronic method for steadiness evaluation, it is, of course, necessary to filter out the steady-state frequency generated by the shutter in the projector and to replace the carbon arc with a voltage-stabilized incandescent lamp to obtain the required constant light intensity.

Electronic Circuit Operation

Those familiar with electronic circuit design fully appreciate the many different types of circuits which could be used to obtain a recorded output voltage directly proportional to image displacement under the conditions noted above. Although considerable improvement can be made in the circuit, shown in Fig. 3, the results obtained with it were quite satisfactory.

The operation of the circuit is briefly as follows:

A fraction of the photocell output voltage, developed across the gain potentiometer in the control grid circuit of the pentode, V_1, is amplified by V_1 and to a small extent by the transformer in its anode circuit. The secondary of

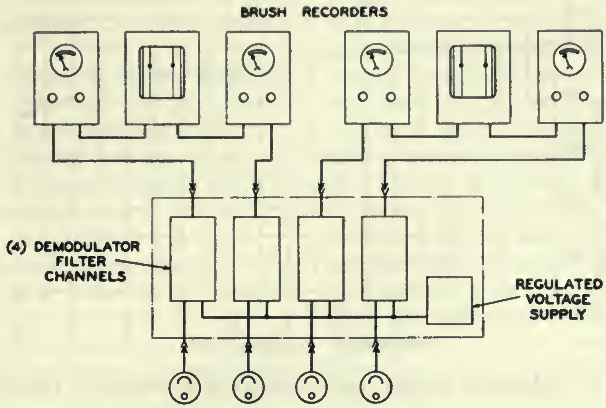


Fig. 4. Photoelectric steadiness evaluator for motion picture film images—block diagram.

this transformer is connected to a full-wave germanium diode bridge rectifier from which is obtained a d-c voltage proportional to the intensity of the pulsating light falling on the photocell. The twin "T" null-type filters, connected in cascade, effectively remove the steady-state ripple frequency components from the rectified d-c voltage. The output from the above filter circuit is connected to the grid of V_2. This tube, connected as a cathode follower, is used principally as an impedance transformer.

The low source impedance, characteristic of cathode followers, permits the use of a voltmeter as an output indicator and provides a convenient means for the mixing of outputs from different photocell channels. Thus, the recorders which are shown in the block diagram, Fig. 4, may be connected directly, as indicated, to the output from the demodulator filter channels or, if desired, the outputs from the channels may be combined to obtain relative steadiness data. For example, the change in the output voltage from the channel supplied by photocell A, Fig. 2, due to longitudinal position variations of the image boundary, may be combined with the output voltage from the channel supplied by photocell E and the difference or unbalanced voltage recorded. The voltage variations so obtained would be a measure of the motion of the film image relative to the perforation and would be indicative of the unsteadiness contributed by the camera and/or printer.

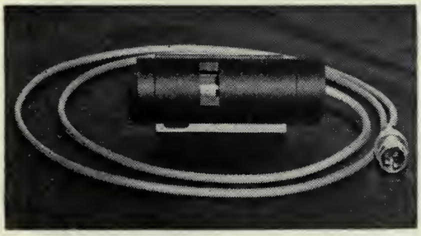


Fig. 5. Photocell housing; window ½ in. wide.

To facilitate the mixing of the photocell demodulator channel outputs, two of them supply a positive output potential with increasing light, whereas that of the remaining two supplies a negative potential. Aside from this output polarity reversal, the channels are electrically identical.

A frequency-characteristic curve of the channel gain as a function of modulation frequency is shown in Fig. 6. Ideally, this response should be flat from approximately $\frac{1}{2}$ to 10 cycles/sec.

A photograph of the steadiness evalu-

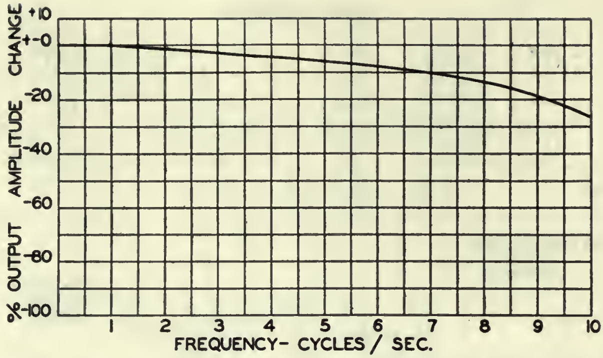


Fig. 6. Frequency-output characteristics of demodulator channel.

ator console and one of the console with the Brush Recorders mounted on a shelf in the back of the projection test screen are shown in Figs. 7 and 8, respectively.

Instrument Adjustment and Operation

The accuracy of the photoelectronic method for evaluating steadiness is contingent upon the conditions listed below:

1. The intensity of the projector light source during the test should be constant.

2. The light flux distribution on the viewing screen, in the absence of film, should be uniform over the photocell window positions.

3. The projector shutter speed should be constant; and if the null-type filters are used, these filters should be adjusted for the specific frequency generated by the shutter and the twice frequency ripple component resulting from the full-wave rectification of the amplified photoelectric a-c voltage.

4. The windows or openings in the photocell enclosures, Fig. 5, should be square or rectangular and each should have the same physical size and orientation relative to the photocell.

5. The light sensitivity of the cathode surface of the photocell over the window area should be constant.

6. The output voltage from each of the photocell channels should be adjusted to give the same value when the

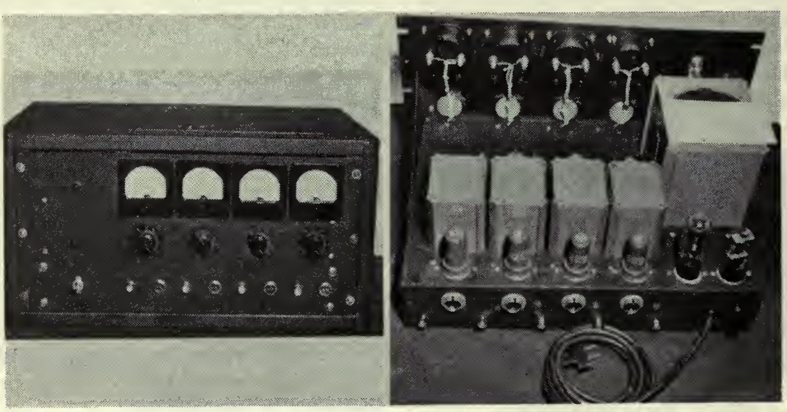


Fig. 7. Steadiness evaluator console.

photocells are fully illuminated at their respective positions on the viewing screen.

7. The differences in the sharpness between the clear and opaque areas of the film should be relatively small.

8. The recorded voltage output, as a function of frequency, should be constant from approximately $\frac{1}{2}$ to 10 cycles/sec.

9. The film density variations in the clear and opaque areas should be small.

The practical operation and application of this instrument for evaluating steadiness will be readily understood if we consider, in somewhat more detail, the adjustment of the instrument for recording the longitudinal component of steadiness. Consider again Fig. 2. In this illustration, the photocell housings have been removed for convenient representation. In actual use, the average position of the boundary between the cross-hatched and clear areas approximately bisects the windows of the enclosures. As previously stated, it is essential that the change in the output voltage from each of the photocell channels should be the same when the windows of the photocells are, first, fully within the clear portion of the image, and, then fully within the cross-hatched portion. This is conveniently done by setting the gain potentiometers in the grid circuits of V_1, Fig. 3, to zero and adjusting the meter-"zero set" potentiometers until the output meter in each channel indicates zero volts. The picture image, Fig. 2, is then framed downward, fully illuminating the windows of photocells A, C, D, G and E. Having done this, the gain potentiometers in the grid circuits of V_1 are adjusted until the output meters read midscale or one volt.

The film image is then framed upward so that the cross-hatched portion of the image fully covers the windows of the photocells and the output meter readings are noted. If the meter readings are other than zero, it indicates that some light is being transmitted through the cross-hatched portion of the film, which may require compensation. The compensation is accomplished by readjusting the meter-set potentiometers to obtain a

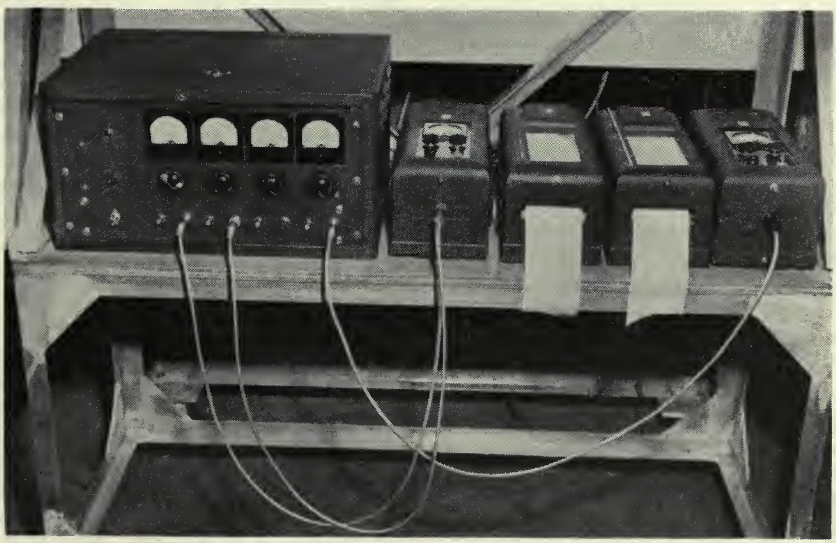


Fig. 8. Steadiness evaluator console and recorders back of test screen.

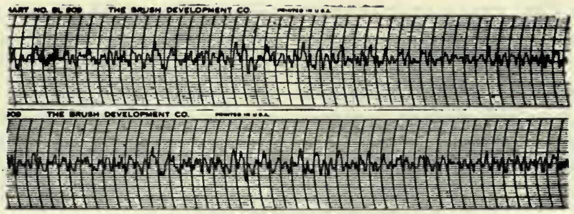


Fig. 9. Transverse position variations of frame image for two consecutive passes of test film through projector.

zero reading on the meters and framing the image of the film downward, until the photocell windows are again fully within the clear area. The gain potentiometers are then increased until the output meters read midscale or one volt. If, when the film image is again framed upward, the output meter readings are greater than approximately 0.1 v on any channel, the process is repeated. This is seldom necessary, however, for with reasonable care in preparing the film, the cross-hatched density is very high compared with that of the clear area and compensation is not required. The channels fed by photocells B, H and F are adjusted similarly by moving the test projection screen transverse to the image.

After the channel adjustments noted above have been made, the recorders are calibrated. In the tests conducted with the instrument, relative to the evaluation of the steadiness of the several perforation proposals previously referred to, the calibration was set for one small chart division for each 0.01-in. displacement of the image relative to the screen. This 0.01 in. was equal to an equivalent displacement of 0.0002 in. at the aperture on the projector.

The overall accuracy of the system is indicated in part by the similarity in the recorded chart patterns shown in Fig. 9. These curves represent the transverse positional variations between the image (photocell B), Fig. 2, and the perforation (photocell F) for two consecutive passes of the test film through the projector.

A few of the photocell combinations which may be used for obtaining specific steadiness components are listed below.

Steadiness Components of Frame Image Relative to Screen

1. Longitudinal Component—output from channel fed by photocell A;
2. Transverse Component — output from channel fed by photocell B; and
3. Rotational Component — unbalanced output from channels fed by photocell C and photocell D.

Steadiness Components of Frame Image Relative to Perforations

1. Longitudinal Component—unbalanced output between channel fed by photocell A and channels fed by photocell E and photocell G connected in parallel through suitable decoupling resistors; and
2. Transverse Component — unbalanced output between channel fed by photocell B and channels fed by photocell H and photocell F connected in parallel through suitable decoupling resistors.

The photoelectronic method of evaluating steadiness described herein has proven to be of value in supplying *recorded* qualitative and quantitative steadiness data. These *recorded* data are particularly useful in supplementing the information obtained by the visual inspection method of steadiness evaluation.

Sound Track on Eastman Color Print Film

By C. H. EVANS and J. F. FINKLE

The photographic image in the sound-track area of Eastman Color Print Film, Type 5381, is composed of metallic silver plus dye. The normal sensitometric specifications for sound negatives used in release printing on black-and-white materials are also suitable for negatives to be printed on Type 5381. The sound track should be printed by light which has been filtered in such a manner that the dye component of the developed image will be neutral. In general, the sound quality of neutral prints on Type 5381 is comparable with that of prints on Eastman Fine Grain Release Positive Film, Type 5302, but the latter has superior response at the higher frequencies.

EASTMAN COLOR PRINT FILM, Type 5381, is a 35-mm integral tripack three-color subtractive film, designed to be printed from picture negatives taken on Eastman Color Negative Film, Type 5247. In processing a release print on Type 5381, the initial stages are common to the picture and to the sound track. First, the images are developed to metallic silver plus dye. Next, the film passes through a fixing bath which removes all undeveloped silver halide, and then through a bleach which converts all silver to silver bromide. Following the bleach, the sound-track area alone is treated by application of a reducing agent. This converts the silver bromide of the sound track back into metallic silver. The reducer is washed from the film by a water jet, just before the film enters a wash tank. From that point on, picture and sound track again receive identical treatment. The resultant sound-track image is composed of both dye and metallic silver.

Communication No. 1402 from the Kodak Research Laboratories, a paper presented on May 4, 1951, at the Society's Convention in New York, by C. H. Evans and J. F. Finkle, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y.

Sound-Track Printing and Densitometry

In general, sound tracks on Type 5381 are printed from black-and-white negatives. There are two variables in the printing operation which can be used for controlling sound quality. One of these, the amount of exposure, controls the print density. The other, the color quality of the printing light, controls the shape of the H&D (D − log E) curve pertaining to the sound track. The characteristic curve of each individual layer is determined by the properties of its emulsion, and by the development which it receives. The latter is dictated by the requirements of the picture. Redevelopment of the sound-track silver after bleaching is a process which goes rapidly to completion, and so is not suitable for regulating gamma. The characteristic curve of the film as a whole is the sum of the curves of the individual

layers. Varying the relative exposures of these layers, by changing the color quality of the printing light, causes a change in the composite curve. Maximum gradient is obtained when the light produces an image, the dye component of which is neutral, because then each of the individual layers contributes density throughout the range of total density. As it turns out, this condition yields the best sound prints, both variable-width and variable-density.

Because the sensitivities of the individual layers vary considerably among themselves, it is necessary to filter the printing light in order to obtain a neutral print from a black-and-white negative. A pack composed of several filters will be required. The combination of a photometric filter with color-compensating filters is recommended because it requires the least number of elements. This is important because it minimizes surface losses. Experimentally, it was found that the available exposure was doubled in changing from a 6-element to a 3-element filter pack. In printing sound, it is not necessary to include in the filter pack an ultraviolet-absorbing filter such as that used in printing the picture.

To make neutral prints of proper density on a Bell & Howell Printer, Model D, operated at 90 ft/min, it has been found necessary to use a high-intensity light system, utilizing a concave mirror and a 300-w tungsten lamp.

In selecting filters to produce a neutral image, it is helpful to employ sensitometric methods. One manner in which this can be done is as follows: First, by use of a IIb sensitometer a step tablet is made on a motion picture film, preferably on the type to be used for the sound negative. This is printed onto Type 5381 in the sound printer, using a combination of filters which is known to produce an approximately neutral image, for example, a Kodak Wratten No. 86 Filter plus Kodak Color Compensating Filters, CC-20Y and CC-10M. The print is processed *without* redeveloping silver in the sound track. Then, by trial and error, any necessary changes are made in the filter pack until a visually neutral print is obtained. Next, the blue, green and red densities of the steps of this print are determined on a suitable densitometer, and are plotted in the form of H&D ($D - \log E$) curves. This set of curves then serves as a standard with which other sets can be compared. Deviations from the standard will indicate quantitatively any changes in filters which may be required. To maintain maximum available exposure, a minimum of filters should be used. In changing a filter pack to obtain a neutral image, one should always be alert to the possibility of accomplishing this end by removing a filter rather than by adding one, for example, by removing magenta rather than by adding green.

A typical set of standard curves obtained by use of a Western Electric RA-1100-B Densitometer is shown in the right-hand panel of Fig. 1. Integral blue, green and red densities of a neutral strip were determined by employing, respectively, the "blue-printing" filter supplied with the densitometer, a Kodak Wratten No. 58 Filter, and a Kodak Wratten No. 25 Filter. As a matter of general interest, a set of equivalent neutral density curves, determined from the same neutral strip, is shown in the left-hand panel of the figure.

In densitometry of the composite silver and dye image, the visual method leaves something to be desired. The dyes absorb visible light and, therefore, contribute strongly to visual density, but they are quite transparent to infrared radiation. Since conventional sound reproducers utilize infrared-sensitive phototubes, the signal generated in such a reproducer by the sound track on Type 5381 is attributable almost solely to the silver component of the image. Visual densitometry can, therefore, be quite misleading. For example, an effective density of 1.6 in a variable-width print will have a visual diffuse density of approxi-

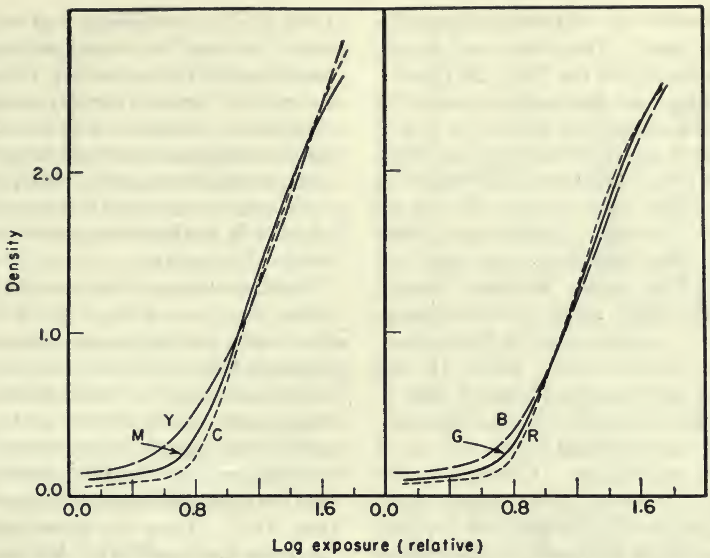


Fig. 1. Density versus log exposure for a neutral print (dye only) on Type 5381. Left: Equivalent neutral densities, magenta, M; cyan, C; and yellow, Y. Right: Integral densities, green, G; red, R; and blue, B.

mately 2.6. Consequently, it is recommended that a physical densitometer be used for reading sound-track densities. It should be equipped with a phototube of the infrared-sensitive type used in reproducers. No filter should be used in the optical system.

All sound-track densities referred to in the remainder of this paper were read on a Western Electric RA-1100-B Densitometer in which the usual blue-sensitive Type 929 phototube had been replaced by a Type 925 phototube. The heat-absorbing glass which is normally present in the optical system was removed. It has been found that densities of neutral sound track on Type 5381 read on this modified densitometer are in good agreement with the actual densities effective in a sound reproducer.

Sound Tests

Distortion, frequency-response, volume-level and signal-to-noise ratio tests have been made on Eastman Color Print Film. In variable-density prints, distortion was determined by the intermodulation method,[1] using 60 cps (cycles per second) and 1000 cps, while in variable-width prints it was determined by the cross-modulation method,[2] using a 9500-cps carrier frequency, amplitude-modulated at 400 cps. All of the negatives used were sensitometrically equivalent to the normal negatives employed in black-and-white release printing, or else they covered a sensitometric range including the normal. Variable-density negatives were exposed on Eastman Fine Grain Sound Recording Film, Type 5373, while the variable-width negatives were exposed on Type 5372.

Neutral prints were made from each negative. Prints exposed with unfiltered tungsten light were made from several of the negatives, and in some cases prints were made using tungsten light filtered by a Kodak Wratten No. 2B Filter, which absorbs ultraviolet. It will be convenient at times to refer to either of the latter two types of print as a "white-light print." The context will make it clear

whether or not the ultraviolet-absorbing filter was used. This filter will be referred to simply as the "No. 2B Filter." Experiments were also made in which the sound-track image was limited to two of the sensitive layers of the print material, but since the results were unfavorable to the use of this method they will not be presented. Finally, comparison prints from the same negatives were made on Eastman Fine Grain Release Positive Film, Type 5302, using unfiltered tungsten light. In making all of these prints, a Bell & Howell Printer, Model D, was used. It was equipped with a Bell & Howell high-intensity tungsten light system, and was operated at the rate of 90 ft of film per minute. Changes in the amount of exposure were accomplished by changing the diaphragm in the optical system, so the color quality of the exposing light remained constant. The voltage supplied to the printer lamp was held at 105 v. It is interesting that no appreciable increase in available exposure could be obtained by raising the voltage above 105 v, because the increasing color temperature required the use of more filters to maintain a neutral image.

The reproducer used in analyzing the prints was a standard Western Electric RA-1251-B Re-Recorder, with infrared-sensitive phototube.

Variable-density intermodulation curves are shown in Fig. 2. Those drawn with a solid line pertain to neutral prints on Type 5381. In order to cover the desired range of sensitometric conditions, nine negatives were used, as indicated in the figure. The curves drawn with dashed lines in the central panel were obtained from comparison prints on Type 5302. They are quite similar to the curves for Type 5381. Volume levels were also measured on the prints of Fig. 2. The prints on Type 5381 were found to

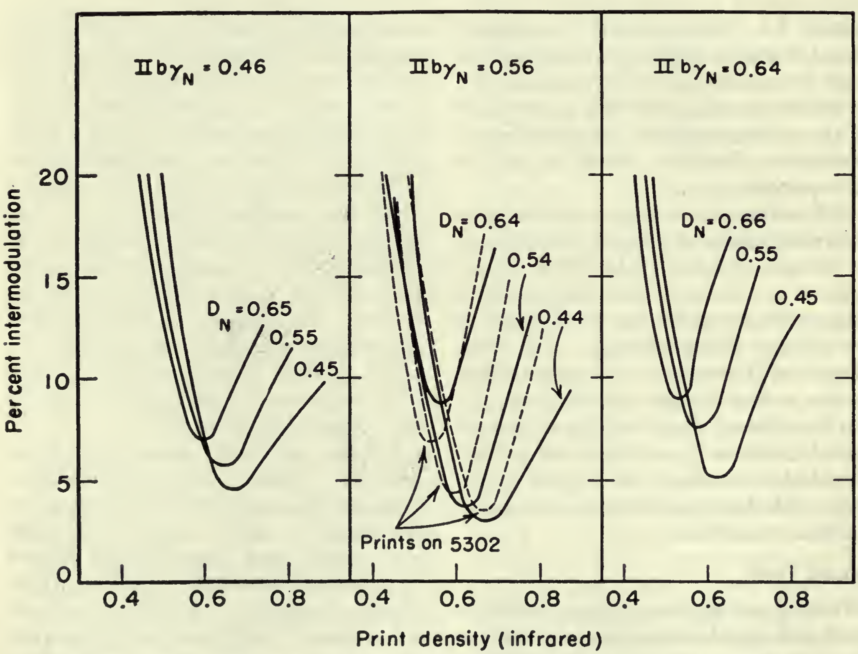


Fig. 2. Intermodulation. Neutral prints on Type 5381 from negatives on Type 5373, reference prints on Type 5302.

run from 3 to 4 db higher in volume than corresponding prints on Type 5302.

In Fig. 3 are shown additional intermodulation curves. These compare a neutral print with two other prints, one exposed with unfiltered tungsten light, and the other exposed with tungsten light from which the ultraviolet was removed. A single negative, of normal density and gamma, was used. It will be noted that the optimum print density for the white-light prints is considerably higher than that of a neutral print. At the points of minimum intermodulation, the volume level of the neutral print is 7 db above that of either white-light print. A portion of this difference is attributable to the lower optimum print density of the neutral print, the remainder to its higher gradient.

Variable-density frequency-response curves are shown in Fig. 4. These have been corrected to show film losses only; scanning-slit losses are not included.

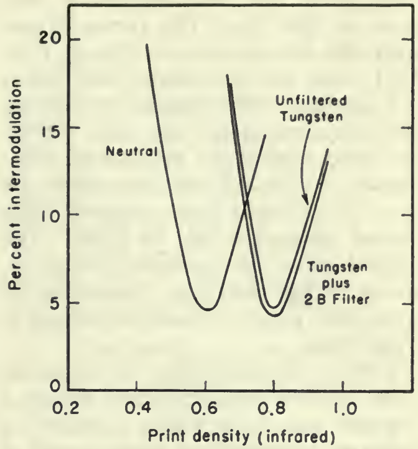


Fig. 3. Intermodulation. Comparison of white-light and neutral prints on Type 5381, from normal negative on Type 5373.

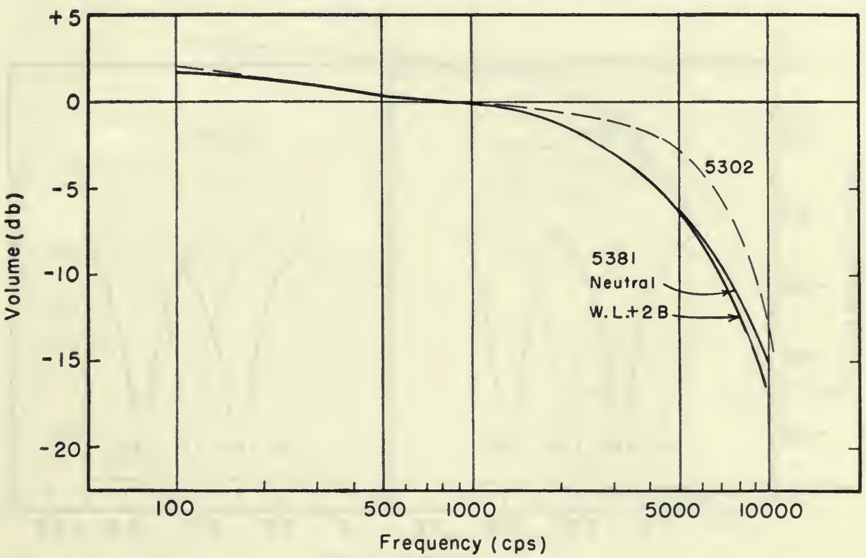


Fig. 4. Variable-density frequency response, referred to zero level at 1000 cps. Comparison of white-light and neutral prints on Type 5381, from normal negative on Type 5373, reference print on Type 5302.

Each curve has been referred to zero level at 1000 cps. The curves drawn with solid lines pertain to prints on Type 5381, while the curve drawn with dashes is a reference curve obtained by printing the same negative on Type 5302. Of the two solid curves, the upper one corresponds to a neutral print, the lower one to a print made with tungsten light filtered through a No. 2B Filter. The neutral print has somewhat better response at high frequency than does the white-light print, but both are inferior to Type 5302.

For the determination of signal-to-noise ratio in variable-density prints, a negative was made which contained a 1000-cps recording, and a long section of unbiased, unmodulated track at the same density. Prints made from this negative were run on the re-recorder, and the relative outputs of the two sections were found. An 8000-cps low-pass filter was used to eliminate high-frequency noise. The signal-to-noise ratio of a neutral print on Type 5381 was found to equal that of a print on Type 5302, but that of a white-light print was 5 db lower.

To turn now to variable-width prints, cross-modulation curves obtained by using a negative recorded at several different densities are shown in Fig. 5. The family of curves at the left refers to neutral prints on Type 5381, while that at the right refers to prints on Type 5302. In each case, curves are shown for three different print densities. Negative-density latitude does not vary greatly with print density and, at a cross-modulation product of −32.5 db, it averages 0.26 for prints on Type 5381, and 0.30 for prints on Type 5302. The optimal negative densities for the prints on Type 5381 are about the same as those for the prints on Type 5302. It is to be noted that the corresponding print densities are about 0.3 higher on Type 5381 than on Type 5302.

Another set of cross-modulation curves is shown in Fig. 6. In this case, the negative was exposed at a single density. Each print made from this negative was exposed to a series of print densities. At

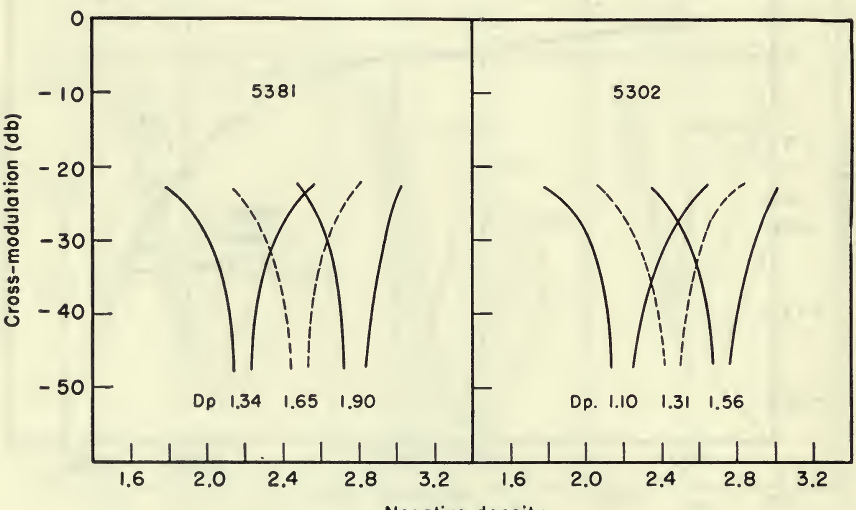


Fig. 5. Cross modulation, three different print densities, negative density variable. Neutral prints on Type 5381 from negatives on Type 5372, reference prints on Type 5302.

the left is shown a pair of curves for white-light prints. The left-hand curve of this pair, drawn with dashes, corresponds to a print made with no filter, while the other curve refers to a print made with an ultraviolet-absorbing filter in the light beam. A reference curve, from Type 5302, lies near the center of the figure. The curve at the extreme right is for a neutral print on Type 5381. All four prints have a print-density latitude of approximately 0.23 at a cross-modulation product of −32.5 db. The optimal print density of the neutral print is considerably higher than that of a print on Type 5302. White-light prints, however, have optimum print densities which are too low for good wearing quality.

Figure 7 presents frequency-response curves measured on variable-width prints. The individual curves have been referred to zero level at 1000 cps. Three prints on Type 5381 are represented by

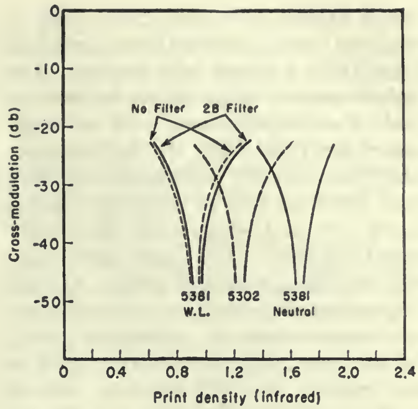


Fig. 6. Cross modulation, single negative density, print density variable. Comparison of white-light and neutral prints on Type 5381, from normal negative on Type 5372, reference print on Type 5302.

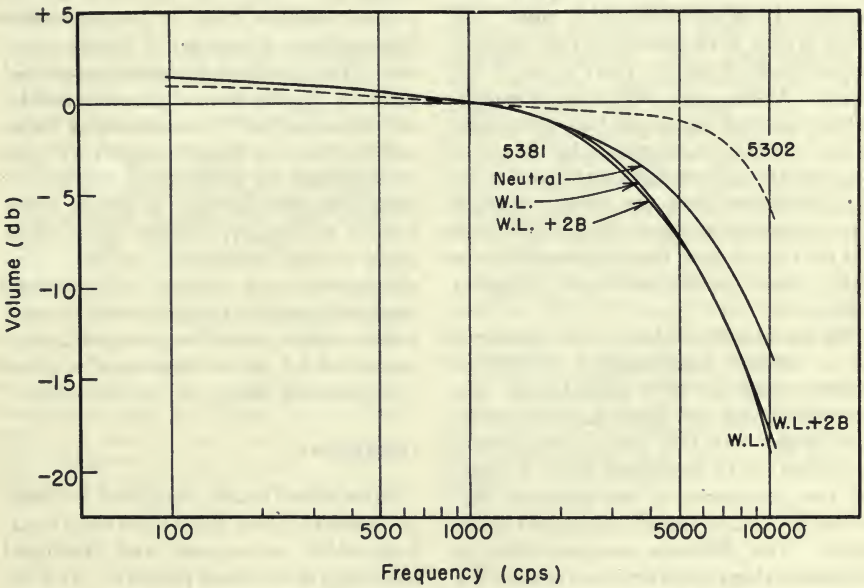


Fig. 7. Variable-width frequency response, referred to zero level at 1000 cps. Comparison of white-light and neutral prints on Type 5381, from normal negative on Type 5372, reference print on Type 5302.

curves drawn with solid lines, while a reference curve, obtained from a print on Type 5302, is drawn with dashes. The high-frequency losses shown do not include scanning-slit losses. Of the three curves for Type 5381, the bottom pair, which are scarcely distinguishable from each other, pertain to white-light prints made with and without the ultraviolet-absorbing filter. The upper solid curve was read from a neutral print. At high frequencies, this print has definitely better response than the white-light prints, but all three are inferior to Type 5302 in this respect. At 1000 cps, the volume level of the neutral print was 0.9 db lower, and that of each white-light print was 1.5 db lower, than that of the print on Type 5302.

Signal-to-noise ratio in variable-width prints was determined by two different methods. The first method is similar to that used for variable density, the level of unmodulated, unbiased track being compared with that of a recorded 1000-cps signal. In a variable-width print, the noise which is measured in this manner arises chiefly from the clear areas of the print. Again, an 8000-cps low-pass filter was used to cut off high-frequency noise. Signal-to-noise ratio for the reference print on Type 5302 was found to be 3.1 db higher than the value obtained from a neutral print on Type 5381, and 2.4 db higher than that obtained from a print made with unfiltered tungsten light.

By the second method, noise measured on a section containing a 10,000-cps record made at 80% modulation, was compared with the signal level of a 1000-cps record. In this case, an important contribution to measured noise is made by the granularity of the boundary between the image and the clear area of the print. The 8000-cps low-pass filter in the measuring circuit serves to remove the 10,000-cps signal, leaving only the components of noise with frequencies below 8000 cps. Signal-to-noise ratio for the reference print on Type 5302 turned out to be 1.5 db higher than the value for a neutral print, and 1.1 db higher than the value for a print made on Type 5381 with unfiltered tungsten light.

It will be noted that both types of variable-width noise measurement indicate a slight superiority of the white-light over the neutral print. The low print density of the white-light print, however, would probably lead to a reversal in this relationship after repeated projection.

As indicated previously, the entire series of tests just outlined was printed without varying the lamp voltage. The color quality of the exposing radiation was thus held constant throughout a given print. Limited variable-density intermodulation tests were made in which the exposure of "neutral" prints was varied by changing the lamp voltage. No change was made in the filter pack; therefore, the color balance of the image changed with density level. The diaphragm opening, however, was carefully chosen to yield optimum print density at a color balance close to neutral, when printing from a negative of average density. The resulting distortion curves did not vary greatly from those obtained by the other method. In controlling exposure by means of lamp voltage, care must be exercised to avoid large departures from neutrality, as these would be detrimental to quality. Other experiments made in this connection, on both variable-density and variable-width prints, have indicated that departures from neutrality which could be corrected by a change of 0.1 in the density of a color-compensating filter, can be tolerated.

Conclusions

Satisfactory sound prints can be made on Eastman Color Print Film from negatives which are exposed and developed according to standard practice. It is not necessary to use negatives of abnormal density or contrast. The dye-plus-silver sound track which is obtained is well suited to existing reproducers.

Prints should be exposed with radiation of a quality which will produce an approximately neutral image in the sound track. Printing with unfiltered tungsten light is not recommended for either variable-density or variable-width sound tracks, because in each case the resulting prints are inferior to neutral prints in some respects. Although an ultraviolet-absorbing filter is necessary to preserve correct color balance in making prints from color-picture negatives, it has no appreciable effect on the balance to tungsten light when printing from black-and-white sound negatives.

Acknowledgment

We are pleased to acknowledge the assistance given by several members of the Color Process Development Department, Kodak Research Laboratories, with whom we have conferred on problems relating to exposure and development.

References

1. J. G. Frayne and R. R. Scoville, "Analysis and measurement of distortion in variable-density recording," *Jour. SMPE*, vol. 32, pp. 648–673, June 1939.
2. J. O. Baker and D. H. Robinson, "Modulated high-frequency recording as a means of determining conditions for optimal processing," *Jour. SMPE*, vol. 30, pp. 3–17, Jan. 1938.

Discussion

John Stott: I believe Eastman Color Positive Film has speed relationships within the three layers which make it possible to print this film with essentially tungsten illumination with a 2B filter in the light source, so long as you use the Eastman Color Negative Film as your negative material. If that is the case, why is it not possible when you make the sound track, if you are looking for a neutral sound track, to use a piece of Eastman Color Negative Film that has been fixed out and use that as your filter?

C. H. Evans: I think that would be possible. We haven't used that method. It might take some color compensating filters in addition.

John P. Byrne: My question is one of an amateur regarding color. I don't know anything about it, practically, but we will have to think in terms of color at the Signal Corps from now on, I believe. How do you get your three separate curves, each one from a single emulsion layer? Are they exposed in a sensitometer to three different filters to get the cyan, magenta and yellow values? If this is the case, how do you superimpose those three to get your density equivalent?

Mr. Evans: Do you refer to those curves which we showed in Figure 1?

Mr. Byrne: Yes.

Mr. Evans: Those were read on the entire film. That is, we had a single neutral densitometric dye strip, without any silver. The three integral density curves were read on the ERPI (Electrical Research Products, Inc.) Densitometer. The first curve was read using the blue printing filter; the procedure was then repeated on the same strip using the green filter, and again, using the red filter. The densities determined in this way are integral densities and they don't really separate completely the individual contributions of each of the three layers.

J. G. Frayne: Are these losses that you report at high frequencies inherent in the dye structure? Or are they brought about by the silver sulfide in your process?

Mr. Evans: This is not a sulfiding process. You just get silver and dye. I would say that such losses are inherent in a tri-pack film, where you have to print in all three layers.

Simultaneous High-Speed Arc Photography and Data Recording With a 16-Mm Fastax Camera

By EUGENE L. PERRINE and NELSON W. RODELIUS

In order to correlate photographs with other recorded data, the optical system of a galvanometer oscillograph was modified so that it could record on the film in the exposure aperture of a 16-mm Fastax camera. The addition of the galvanometer system required no permanent alterations of the Fastax camera and provided a record in the form of a spot which moved horizontally in the field of view when the film was projected.

As HAS BEEN the case in most other high-speed motion pictures of welding arcs, the photographs made by us were only one phase of a study of the arcs. Other information was recorded simultaneously by pen recorders and a six-channel galvanometer oscillograph. After the experiments were partially completed it was found impossible to correlate the action in the motion pictures with the other recorded information. To overcome this difficulty, a galvanometer was added to the Fastax so that the same signal that was recorded on one channel of the oscillograph could also be recorded on the Fastax film. With this arrangement, it was possible to relate any action seen in the picture to variations in the recorded data.

The photographs required for welding arc studies are close-ups. Usually only the tip of the electrode, the arc, and a small area of the piece being welded are included in the field covered. In most cases a field one-half inch high was adequate. To cover this area without placing the lens too close to the arc, a 113-mm focal length, $f/4.5$ Bausch & Lomb Tessar was used. The mounts for this and similar lenses used in our laboratories were made in our own shop. They consist of a brass tube with adapters to fit the different lenses and a series of interchangeable tubes of various lengths which telescope with the lens tube and are fitted to the lens mount of the camera (Fig. 1). With these tubes and a series of lenses ranging in focal length from 17 mm to 6 in., we are able to focus at any distance from infinity to less than one inch. They make possible any desired image size on the film up to a magnification of ten times.

The brightness of various welding arcs differs over a range of more than one hundred to one, but in all cases it is very high. In addition to the use of small apertures, it was necessary to use filters

Presented on May 2, 1951, at the Society's Convention at New York, by Eugene L. Perrine and Nelson W. Rodelius, Armour Research Foundation of Illinois Institute of Technology, 35 West 33 Street, Chicago 16, Ill.

Fig. 1. Lenses, adapters, and extension tubes used with the Fastax camera.

to reduce the light reaching the film. Filter combinations having factors of about fifteen were used with Eastman Super X film, at 5000 frames/sec, and apertures of from $f/16$ to $f/64$. These filter combinations were also used to select various portions of the spectrum when it was desirable to accentuate certain parts of the arc. Pictures made with Kodachrome film and neutral-density filters were found less satisfactory than those made on black-and-white film, because of the shorter scale of the Kodachrome. A special holder was constructed for the filters (Fig. 2). This holder also held a cover glass which protected the filters from splattering metal.

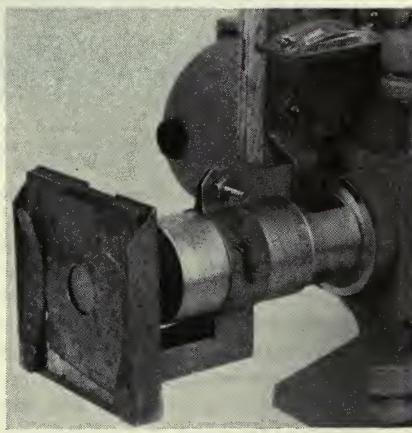


Fig. 2. Filter holder.

A carriage mounted on a track carried the welding electrode. A camera support was constructed and attached to the carriage so that the camera always followed the arc during the operation. A microswitch mounted on the track was operated by the carriage to start the camera. Manual operation of the camera was sometimes more desirable in order to make possible the photographing of the arc at the most advantageous moment, e.g., when the arc was least obscured by smoke.

The timing-light in the Fastax was used to provide a record of camera speed, but after a few films had been viewed and the data recorded by the

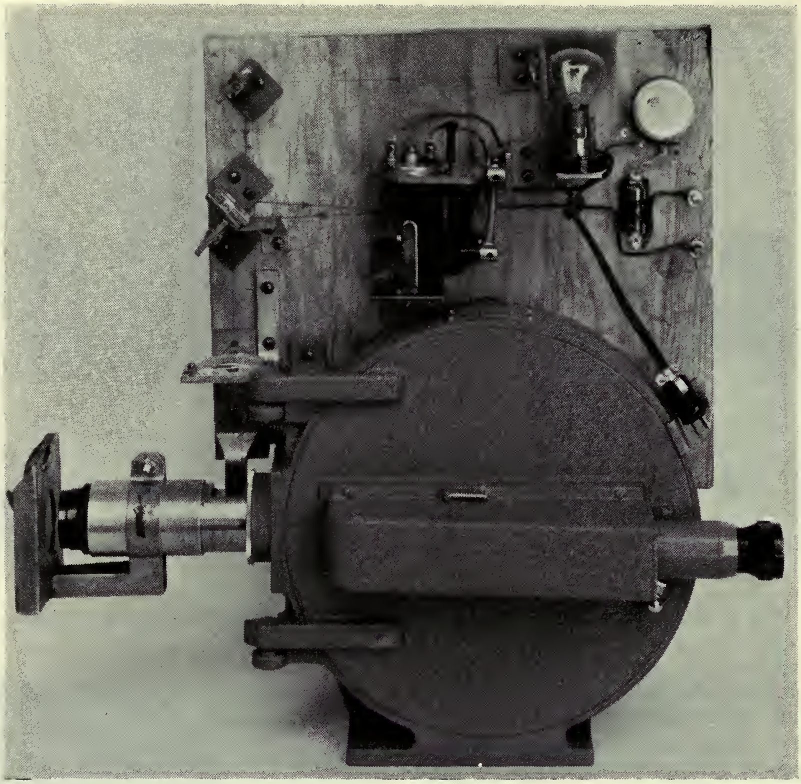


Fig. 3. Galvanometer assembly on the Fastax camera.

oscillograph examined, it was apparent that more than a record of camera speed was needed to relate the action to the recorded data. The use of synchronizing pulses on the timing-light of the camera and one channel of the oscillograph was considered. This would have required the construction of a system for generating coded pulses and also the additional work of a frame-by-frame examination of the film to associate the marks on the edge of the film to the related frame. Instead of using the synchronizing pulses, a way was devised for mounting one of the galvanometers from the oscillograph on the Fastax camera.

In making this addition to the camera, two major problems had to be solved. First, the galvanometer system had to be attached to the camera in such a way that the future operation of the camera was unimpaired. It was desirable, although not mandatory, to make the additions in a fashion which would leave the camera available for other work during any break in the arc study. Second, the light from the galvanometer optics had to be improved to provide adequate exposure on the faster-moving film of the camera.

The first of these problems was solved by folding the optical path of the galvanometer system and bringing the light beam into the camera through a hole cut in the top of the lens extension tube. Figure 3 shows the entire assembly, including galvanometer, light source, mir-

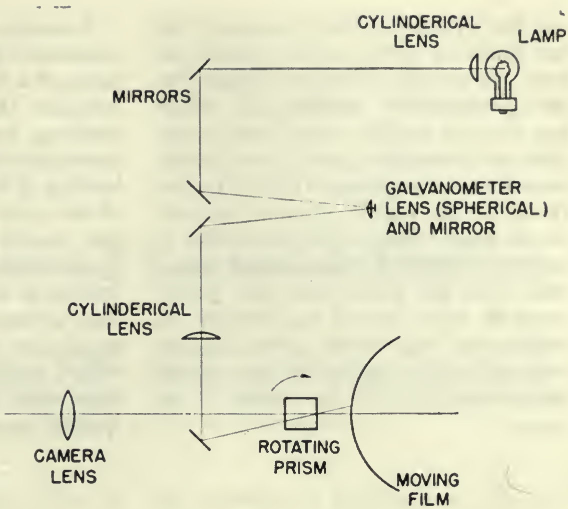


Fig. 4. Optical system of galvanometer mounted on Fastax camera.

rors and lenses. This assembly was mounted on a piece of $\frac{3}{4}$-in. plywood which provided a rigid support; it was easily held on the side of the camera with two clamps, and could be temporarily removed from the camera without loss of adjustments. First-surface mirrors were used throughout. The mirror mounted inside the extension tube was placed sufficiently below the optical axis of the camera so that none of the light passing from the camera lens to the film was intercepted. This was to avoid any change in the exposure of the picture. Because the apertures used were small, this was easily accomplished. Interference would probably be inevitable with high relative apertures. Focus of the light spot and amplitude of the galvanometer were set with the lens removed from the camera so that the spot could be observed directly in the exposure aperture. The view-finder could not be used because the light entered the aperture from below the axis and was imaged at the top of the aperture. Rays following this path never enter the relay lens in the view-finder.

When operated at 5000 frames/sec, the film in the 16-mm Fastax camera moves about five times the paper speed used in the oscillograph from which the galvanometer record was obtained. The paper has a sensitivity nearly as great as Eastman Super XX film, so that no exposure increase is obtained with the recording material. The light source was a 6–8 v, 50-cp auto headlight bulb which was turned so that the optical system imaged the edge of the filament. To increase the brightness of the spot during exposure, the voltage on the bulb was advanced to just below the burn-out value. Also, two cylindrical lenses were added to the system. One placed near the lamp imaged it on the moving mirror of the galvanometer. A second cylinder, just above the lens extension tube, shortened the line image resulting from the first cylinder to a slightly elongated spot (Fig. 4). This spot was of adequate brightness to compensate for the increased writing speed in the camera.

The galvanometer record appeared as a spot which moved horizontally in the bottom of the frame of the projected motion pictures. The spot size was slightly larger than the thickness of the coiled filament in the lamp used. Only slight improvement could have been obtained by using a slit over the lamp or

the first cylindrical lens, because of the low resolving power of the optical system. As a result, the traces obtained on the galvanometer oscillograph, which has a much greater swing than is possible on 16-mm film, gave a more precise record than was obtained on the Fastax. However, the records obtained directly on the Fastax frame made it possible to see what electrical changes were associated with the action that was photographed, and when it was desired, an oscillogram was made simultaneously with the motion picture so that precise measurements could be made of the trace.

Examples of other uses for the galvanometer–Fastax system are: (1) the firing of a flash bulb where the filament burn-out time is to be related to the burning; and (2) the operation of an electrically driven impact tool where the loading of the motor at different portions of the cycle is being studied. The system would be useful in many other applications where additional data are needed to determine the exact relationship between controlling or controlled signals and the action photographed, or where several slightly different operations must be associated with their respective electrical counterparts.

Forum on Motion Picture Theater Acoustics

THIS FORUM was sponsored by the SMPE Atlantic Coast Section and the Acoustical Society of America, and was held on June 7, 1949, at New York, William H. Rivers presiding, and Professor Leo L. Beranek acting as Moderator.

Chairman William H. Rivers: This is rather an unusual type of meeting for us to have, but it seems highly worth while. The main gain from this meeting is the technical discussion and the conclusions that may be taken away with us. [After announcements, Mr. Rivers turned the meeting over to the moderator.]

Moderator Leo L. Beranek: I think we will do best today if we treat this meeting as an informal one, and lay ourselves open to asking and answering questions, without worrying about whether this is going on the record or not.

This Forum came to be organized as the result of a letter received a scant month past, and addressed to the SMPE Secretary, from Mr. Lucas, of the British Thomson-Houston Company, Ltd., saying that James Moir was going to be in New York about this date. We thought it would be helpful, knowing the papers that he has published in this field, to learn his thoughts on motion picture theater design, so we cabled him and he consented to be with us today.

We thought it might also be interesting to learn about motion picture theater design in the Scandinavian countries. Uno Ingard, of Chalmers University, Gothenburg, Sweden, studying at MIT in the Acoustics Laboratory, was asked if he would speak on the state of Scandinavian motion picture theater design. He hesitated at first because, he said, there are other people who are experts in this field, and he didn't want to speak as one of the experts. But he did consent to tell us the state of the art as he knows it.

We felt that the important objectives of this meeting should be: (a) to exchange information on an informal basis; (b) to establish what, if any, are the essential differences between practices in Europe and practices in the United States; and (c) to gain ideas on how to better the practices of our own countries.

Having obtained the interest of our Forum visitors, we proceeded to assemble a panel of local experts, who will lead the discussion and answer questions from the audience. These men reserve the right to change their minds if they think better of their answers at some later date. [The panel personnel are listed on p. 159 of this *Journal*.]

I do not wish to give a speech, but I would like to give the general basis of the subject of our discussion.

When sound pictures were first being tried out around the country, they were shown in auditoriums, with rather bad acoustics, that is, the reverberation times were high. It soon became obvious that something would have to be done to the halls if sound motion pictures were to be acceptable. So, a trend developed in the

direction of placing a lot of absorbing material in the rooms, with the result that most theaters became very "boomy." This happened because the absorbing materials selected were efficient only at the higher frequencies. Then, studies were made in the laboratories of some of our larger manufacturers of sound systems. These studies led to the establishment of criteria for motion picture design.

One particular set of studies led to the issuing of a bulletin by the Research Council of the Academy of Motion Picture Arts and Sciences on May 30, 1932, on "Theatre Acoustic Recommendations." In it is a graph of optimum reverberation times versus room volume. Also, Potwin and Maxfield published a paper in which they set forth another curve of optimum reverberation times, much the same as the SMPE curve for small rooms, but indicating somewhat higher reverberation times for large rooms.

It has been my general observation that the recommendations set forth by the Academy of Motion Picture Arts and Sciences and by Potwin and Maxfield have not been adhered to in actual theater design in this country. I believe that most movie theaters are much deader than the optimum reverberation characteristics shown in these booklets would indicate.

I sincerely hope that we shall discuss the trends in the design of motion picture theaters, both with regard to reverberation time and room shaping. I would not be surprised if we should agree that the SMPE characteristics need revising. (At this point, Dr. Beranek introduced Mr. Moir who presented his paper, for which see the following pages of this *Journal;* then Mr. Ingard presented his paper which is also in this issue.)

Pulse Methods in the Acoustic Analysis of Rooms

By J. MOIR

Experience in installing large numbers of a standard sound-film equipment in theaters indicated that sound quality was not related to the overall frequency characteristic or the reverberation time. A pulse technique is described which gives a direct picture of the direct and reverberant sound at any location. The value of the reverberation-time concept as presently defined is questioned and recommendations for the optimum design of theaters are given, based on the results of pulse analysis.

There appears to be little doubt that most first-order defects in the acoustical performance of a room are removed by the application of Sabine's analysis[1] and recommendations. Experience appears to indicate, however, that the second-order defects, though still important, are not corrected by more meticulous application or by elaboration of Sabine's analysis. This is not a statement that can be shown to have precise mathematical justification, but is something that grows upon one as a result of daily contact with the problems.

In our particular case, we were engaged before World War II in installing sound-film reproducers of standard design in a large number of theaters, and we found that the results at the patron's ear varied all the way from very good to "not so good." The differences were sufficient to justify an investigation. As a first step, our Service Division was asked to provide us with a list of theaters in order of merit, all theaters listed having nominally identical equipment. When the list was studied in detail it was found that theaters listed as "above average" were all praised because of their "good intimacy," a factor which we think is termed "good presence" in the United States. The importance of this factor has been further confirmed during additional postwar investigations into the public preference in sound quality. In two areas checked, theaters having equipment of 1930–1932 design were preferred, though postwar equipment made by all the leading firms was available in the area. The result is surprising because the frequency response was very poor and wow and flutter were high, by current standards. In both

Presented on June 7, 1949, as part of the Forum on Motion Picture Theater Acoustics, sponsored by the SMPE Atlantic Coast Section and the Acoustical Society of America, held at New York, by James Moir, British Thomson-Houston Co., Ltd., Rugby, Warwickshire, England.

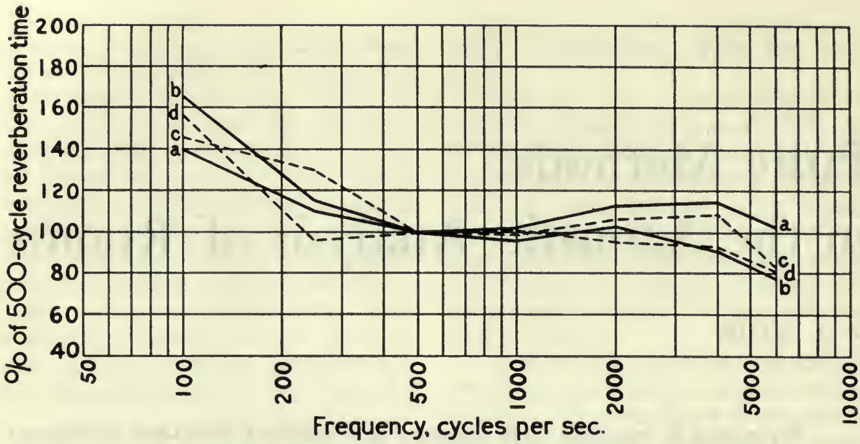


Fig. 1. Reverberation time in different positions in auditorium. a and b: sound quality good; c and d: sound quality bad.

theaters, the "intimacy" was particularly good.

Reverting to the prewar investigation, after a preliminary check to make certain that no normal defects existed, we began to make a more extensive survey of those factors such as acoustic frequency response, reverberation time, etc., factors which are known to be of importance though they are not normally checked in detail on every installation.

Frequency response was not found to present any consistent explanation of the variation in results and this point will not be further discussed.

For various reasons, the differences were considered to be acoustical and we therefore made a more detailed survey of the reverberation time/frequency volume relation. No consistent explanation was found. The results in one particular theater, typical of many others, are indicated in Fig. 1, from which it will be seen that the differences which do occur are small and randomly distributed. The test technique was conventional, a Neuman high-speed level recorder having been used, while the depth and frequency of the modulation of the test tone could be varied over wide limits.

We did have some indication, however, that a greater proportion of the good theaters were to be found with reverberation time below, rather than above, the optimum time/volume relation. The results of twelve of the theaters in the first group tested are shown in Fig. 2. At the time, this was thought to be due to the preferred reverberation time/volume curve being nonoptimum, but we now feel that it is of more fundamental significance. This point will be discussed presently.

Experience gained during this part of the investigation confirmed that the sound-quality preference was based almost entirely upon the closeness of association of sound and picture, the quality we termed "intimacy," and we came to regard this as being connected in some way with the ratio of direct to reflected sound.

Preliminary attempts to measure this were made, but without success until we devised the pulse techniques to be described. This enabled the direct and reflected components to be separated on a time basis and is probably best understood by referring to Fig. 3, a schematic layout of the equipment used.

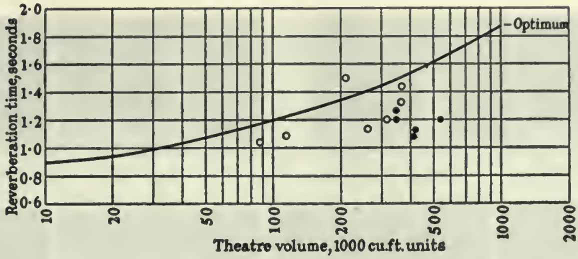


Fig. 2. Theater volume/reverberation time/sound quality results. Black circles: sound quality above average.

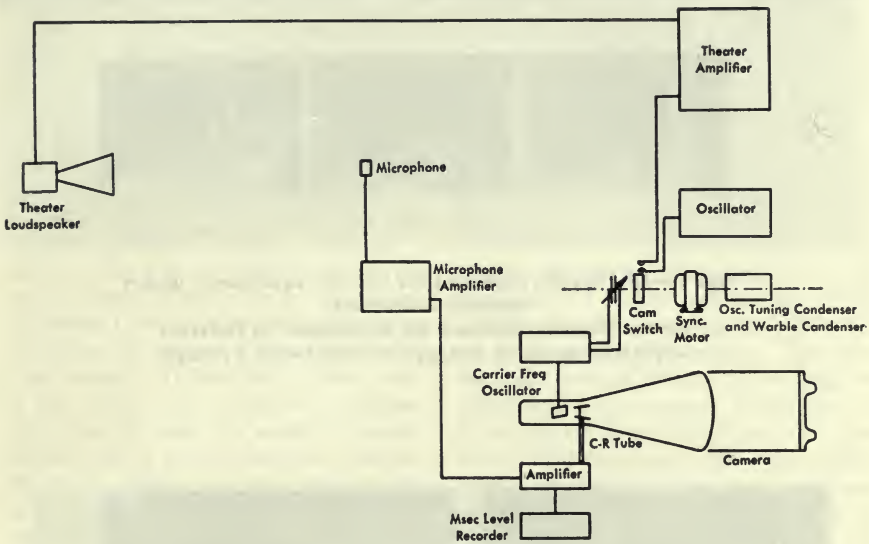


Fig. 3. Setup for acoustic survey in auditorium.

The output from a variable-frequency (audio) oscillator is applied to the input of the theater amplifier through a motor-operated cam switch, which can be set to close circuit for any period between 0 and 50 msec, repeating this at intervals of 1 sec. The frequency of the test tone is set on the oscillator dial in the normal way. This tone pulse is radiated by the theater loudspeakers and is picked up by a sound-cell type of microphone, amplified and applied to produce a vertical trace on a cathode-ray tube. Horizontal deflection of the cathode-ray-tube beam is initiated by the application of the pulse to the loudspeakers, the spot moving uniformly from left to right in about 0.5 sec. Thus, in free space, with no reflections present, the cathode-ray-tube picture consists of a vertical pulse spaced from the origin by a distance proportional to the distance between loudspeaker and microphone. With reflections present, each reflected pulse is spaced from the initial pulse by an amount directly proportional to the difference in path length between the direct and reflected components.

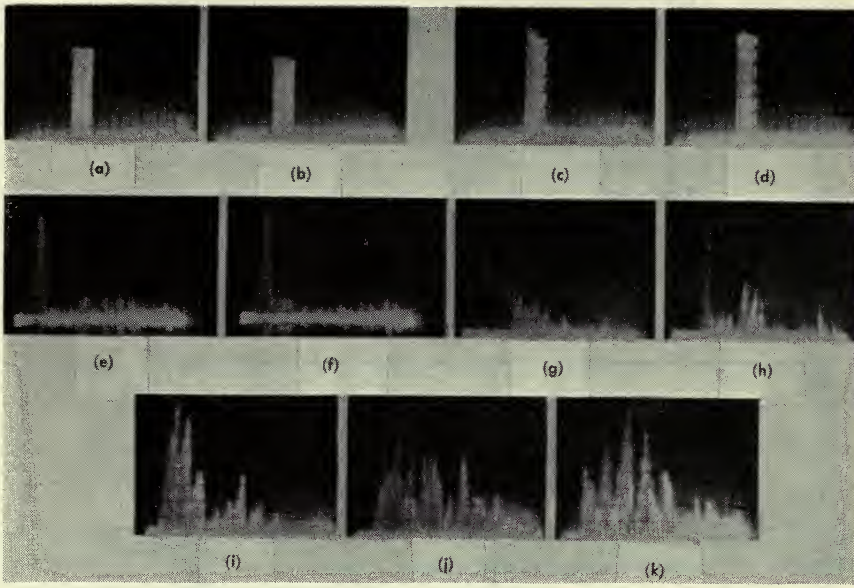


Fig. 4a–4d. Results obtained for theater equipment under open-air conditions;
4e–4k. Results obtained for equipment in theaters ranging from above average to well below average.

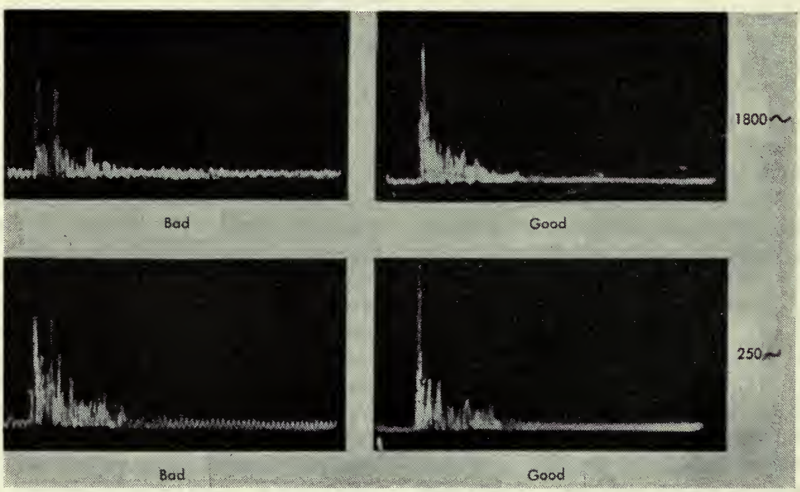


Fig. 5. Changes from bad to good sound quality.

The first four pictures of Fig. 4 illustrate the results obtained for the theater equipment under open-air conditions. The pulse at the input to the theater amplifier is shown in Fig. 4a, the resulting pulse at the amplifier output, in Fig. 4b. Speaker performance is illustrated by Figs. 4c and 4d, taken 4 ft from the high-fidelity horn on the axis, 4c and 30° off the axis, 4d. Pulse shape is seen to be substantially unaltered by the electroacoustic equipment.

The remaining pictures, Figs. 4e through 4k, are selected to show typical results in theaters ranging from above average, Fig. 4e, to well below average, Fig. 4k. In the good location, Fig. 4c, the picture is seen to consist of a well-defined direct pulse followed by a continuous structure of reflections 15 db below the direct sound, whereas the "below average" theater produces a picture, Fig. 4k, in which the direct pulse is almost obscured by a whole series of reflected pulses of greater amplitude, extending for at least 300 msec after the direct sound. It is worthy of note that in this theater, the frequency-response curve was the best of a group of twenty theaters tested about that time, whereas the sound quality was rated as the worst of the group. The reverberation time was close to, but a little above, the optimum value.

Theaters in which good and bad listening positions occurred were of particular importance in the investigation, insofar as all other factors remained constant. Figure 5 illustrates a particular example, where the Service Division was able to draw our attention to two seating positions, fairly close together, but giving widely different subjective results. Pulse pictures taken at two frequencies in both locations are shown in Fig. 5 as typical of our findings, and it will be seen that strong reflections occur in this bad location about 100 msec after the direct sound.

A large number of similar results could be quoted, but it is probably more to the point to mention that we have found no instance of a picture, similar to Fig. 4k, being obtained at a point at which the sound quality was considered to be good. This is true, irrespective of whether the reverberation time was above or below the optimum.

It should be noted particularly that the test method checks the combination of hall and loudspeaker. In a theater it is this combination that is important, for it has been possible to minimize many hall defects by appropriate horn design.

The relationship between reverberation time and the pulse picture is of interest. If a uniform rate of decay of the total sound-energy density is secured, an attenuation of 15 db in 50 msec corresponds to a reverberation time of 0.2 sec, a figure which is certainly on the short side. The figure of 50 msec can be considered only approximate at this stage in the investigation, but if it were doubled, the reverberation time would still be well below any suggested optimum for a theater of 1500 seats. The discrepancy is large and one is tempted to reflect upon our present conception of reverberation time, defined as "the time for a 60-db decrease in the mean sound energy density." It would appear unnecessary to consider the contribution of reflected components attenuated by more than 20 to 30 db. If the sound-energy decay in an enclosure were, in fact, a true exponential curve, neglect of the section of the decay curve below −30 db would not alter the reverberation time as now defined. However, experimental evidence supported by theoretical conclusions suggests that a true exponential decay is the exception rather than the rule. A typical decay curve, taken with a frequency-modulated tone is indicated in Fig. 6, where at least four different rates of decay might be deduced. If a modulated test tone were not used, the departure from a smooth exponential curve would be still greater, and we are inclined to believe that a test technique tends to be judged by its efficiency in

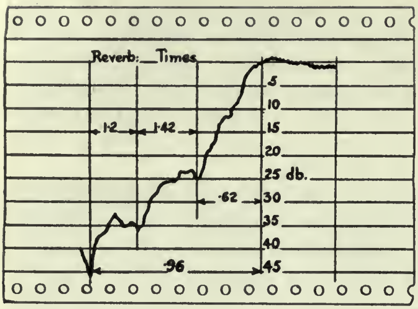


Fig. 6. Multiple decay rates.

turning a nonuniform decay into a smooth exponential decay. In doing this, we rather suspect that much that is of importance is obscured.

We would suggest that a listening point is poor if there is discrete mid-frequency reflection delayed by more than 50 to 100 msec and attenuated by less than 20 db. If this is correct, we should not be worrying about decay periods of 60 db or time intervals in seconds, but should direct our attention to the details of the decay during the first 20 db (or perhaps 100 msec), as we believe that the acoustical character of a room is almost completely determined during this initial time interval. There appears to be strong evidence to support a review of our reverberation–time definition, to place more weight on the initial 20 db of decay.

Earlier in the paper it was noted that preferred theaters appear to fall below, rather than above, the current optimum curve. On the basis of the results reported, it is suggested that this is probably not due directly to the fact that the best reverberation time is to be found on any alternative optimum curve, but is due to the decrease in the chance of getting echoes of high amplitude and long delay as the reverberation time approaches zero. It is believed that if the delayed echo problem were separately controlled, much higher values of reverberation time would be preferred.

The last war brought the investigation to a standstill and, as the building of new theaters in England has been entirely suspended until such time as war-damaged housing is restored, we have had no opportunity of following a design from the drawing-board stage to the final pulse testing, but we have had considerable opportunity to compare pulse results with what we would predict from the plans of the theater.

Let us consider just what we have found from pulse testing and how best to use that information in new designs of theaters.

1. Good sound appears to be associated with a strong direct signal followed by a reasonable amount of low-level reflection to provide room color.

2. The permissible intensity of a discrete reflection is approximately inversely proportional to the time it is delayed behind the direct sound.

3. All discrete reflection should be reduced by at least 20 db if it occurs more than 50 msec after the direct sound.

4. The sound source and all early reflections should subtend the minimum angle at the listening position.

5. There should be no sharp changes in the acoustic impedance along the hall.

As applied to the design at the drawing-board stage, it is advisable, first of all, to apply Sabine's or Eyring's equation to correct the reverberation time in the normal way. When doubt exists, it is well to err on the side of making the reverberation time slightly lower than the present optimum. The reverberation-time frequency characteristic should be controlled, the Knudsen–McNair relation being the best we can suggest, though we suspect that the "rise" called for at the bass end is somewhat excessive.

Regarding theater-shape ratios, a width of 0.7 $\times$ length and a height of 0.35 $\times$ length appear reasonable, though we regard this sort of data as a gross oversimplification of the problem, to be used only in the very first stages of design.

Though the prewar British standard of

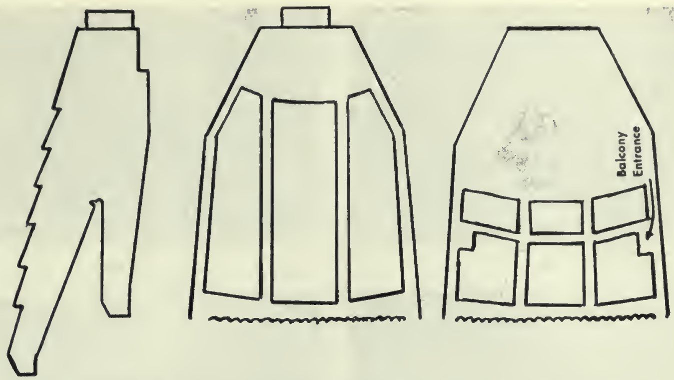


Fig. 7. General indication of preferred shape of theater.

furnishing approximately 140 to 150 cu ft per seat has given satisfactory results, good results have been secured between 120 and 180 cu ft per seat.

When absorbent material has to be added to correct the reverberation time, we regard the ceiling as the least desirable location. Energy flow between floor and ceiling is heavily attenuated by concentration of absorption on the floor, so that it appears desirable to confine any additional treatment to attenuating energy flow in the other modes.

To secure good intimacy, we would suggest the following:

1. Concave surfaces should be avoided, particularly where they face the sound source. A concave back wall is particularly harmful.

2. Large flat surfaces should not be placed where high-intensity direct sound can fall upon them. Diffusion is generally better than absorption, but regular patterns of simple diffusing surfaces should be avoided. Excess diffusion produces a characterless performance. The wall shapes should be such as to avoid echoes having a delay of more than 60 msec occurring at any point within the seating area.

3. A proscenium arch should be avoided and the cross section of the hall should change uniformly.

4. Gangways and entrances should be placed against the sidewalk and not in the center of the theater, a position generally containing some of the best listening areas. (Figure 7 is a general indication of the preferred shape.)

It is appreciated that these suggestions may conflict with building, fire, or site restrictions, but they have been idealized as requirements to be approached as closely as circumstances permit.

When considering cathode-ray tube methods of presenting acoustic data, it is dangerously easy to produce pictures containing so much information that they cannot be readily related to the results of subjective listening tests. The ear is almost insensitive to phase differences which produce large changes in a cathode-ray-tube picture. Because of this, and also because we are at the "crawling" stage in pulse analysis, it is necessary to present the simplest picture. This is met by radiating a pulse with the simplest possible frequency spectrum, a pulse of audio tone several cycles long. The frequency spectrum of a pulse of fixed length increases in complexity as the number of cycles in the pulse is reduced, and there is, therefore, some point in using a pulse consisting of a fixed number of cycles. We have found, however, that this is not justified in view of the decreasing importance of the lower

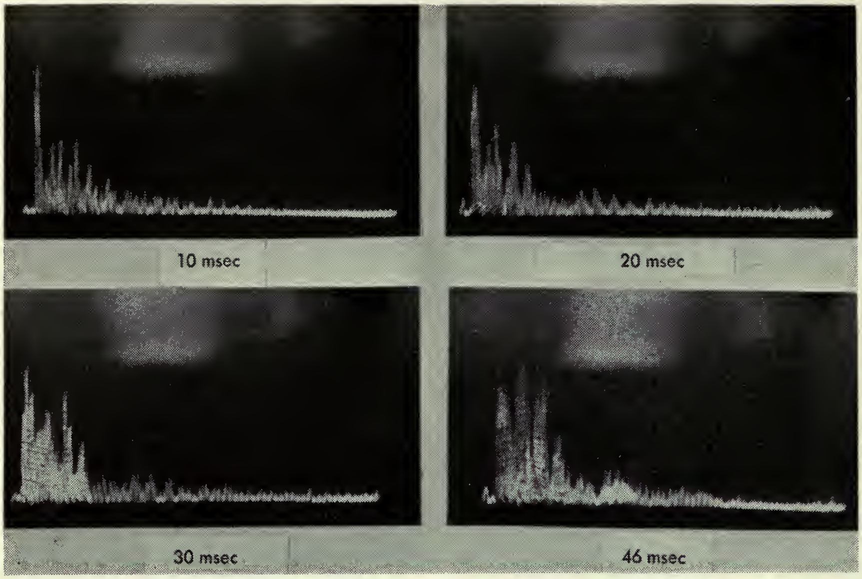


Fig. 8. Changes that occur as the pulse length is increased from 10 to 46 msec.

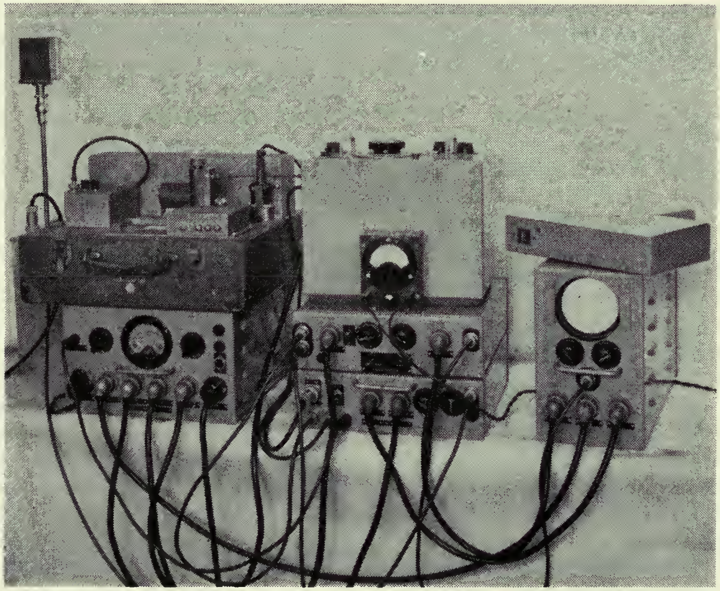


Fig. 9. Test equipment by Messrs. Owen and Webb.

frequencies in controlling intimacy. This has led to our standardizing a pulse length of 10 to 20 msec.

Other investigators have chosen to use short pulses generally produced by a spark discharge, but in our experience this presents so much information covering such a wide frequency band that it defies analysis.

As the pulse length is increased above 20 msec, the pulse pictures tend to lose their simple character due to interference between pulse components that arrive at the microphone position by paths of differing length. Figure 8 is an example of the changes that occur as the pulse length is increased from 10 to 46 msec.

Experience tends to indicate that our subjective assessment of sound quality is in good agreement with the results using a 10- to 20-msec pulse.

While we are certain that pulse methods are a powerful new weapon in exploring an auditorium, we feel that there is still much to be done. At present there is insufficient mathematical background and while we know that strong reflections have deleterious effects upon sound quality, we also know that a complete absence of reflection can lead to unsatisfactory results. The basic question "How much reflection do we want?" can be answered only in broad terms.

Change in our viewpoint and requirements during the investigation led to considerable modification in the test equipment. More recently, the equipment has been carefully rebuilt by Messrs. Owen and Webb as illustrated by Fig. 9, the complete equipment packing into two cases approximately 23 × 16 × 12 in. The basic principles remain as illustrated by Fig. 3.

The pulse technique described was developed during 1937–1940 in close association with C. A. Mason and is more fully described in Reference 2, but a deeper realization of the significance of the pulse technique developed in the immediate postwar years.

We are indebted to H. L. Webb for most of the experimental work and our thanks are due to the Directors of the British Thomson-Houston Co., Rugby, England, for permission to describe the results of the investigation.

References

1. See, for instance, *Architectural Acoustics*, V. O. Knudsen, Wiley, New York, 1932.
2. C. A. Mason and J. Moir, "Acoustics of cinema auditoria," *J. Inst. Elec. Engrs.* (*London*), vol. 88, part III, pp. 175–190, Sept. 1941.
3. J. Moir, "Reverberation time as an index of room performance," Report of the Physical Society (British) Acoustic Group Meeting, 1947, Physical Society, Prince Consort Gardens, Kensington, London.
4. C. A. Mason, "Interpretation of pulse measurements," Report of the Physical Society (British) Acoustic Group Meeting, 1947, Physical Society, Prince Consort Gardens, Kensington, London.

Notes on Movie Theater Acoustics in Scandinavia

By UNO INGARD

In the Scandinavian countries no fundamental or systematic research on acoustics in movie theaters has been done, as far as I know, and, as a non-authority in the field, I am able to give only a brief informal report of some facts about our theaters and what I think is the general opinion on theater design at the moment in Scandinavia.

NATURALLY most of our theaters are rather small compared with the theaters in this country, seldom with as many as a thousand seats. The theaters are used only for moving pictures and not for other kinds of entertainment, so no attention has to be paid, in acoustic design, to such problems as organ music, for example.

The general design data used, determining the main dimensions of the theater, have been learned almost completely from American experience, with slight modifications here and there. To mention some figures from the design data, we believe the volume per seat should be around 120 cu ft for theaters of ordinary size (about 500 seats). The relation between screen size and viewing distance tends in modern design to be kept below 5, although it lies between 5 and 7 in most older theaters. Other dimensions, mainly determined by visual rather than acoustic conditions, are a ratio of 1 : 1.7 between width and length and 1 : 2.5 between height and width; numbers which I think are about the same as the average used in this country.

The designers are well aware of the importance of avoiding echoes of all kinds. Considerable experience of that sort has been obtained from work of a corrective nature. One notable example of corrective design is the new radio house in Copenhagen in Denmark, where an unusual amount of work was done in order to obtain the most satisfactory acoustics in studios and music halls. One of the most obstinate problems met in this work was the elimination of flutter echoes built up through multiple reflections. Correction was accomplished by changing the shapes of the rooms until the echoes were eliminated. This fact gives an example of the difficulty of predicting the appearance of flutter echoes or long-path echoes from

Presented on June 7, 1949, as part of the Forum on Motion Picture Theater Acoustics, sponsored by the SMPE Atlantic Coast Section and the Acoustical Society of America, held at New York, by Dr. Uno Ingard of Chalmers University, Gothenburg, Sweden, and for the present year at the Acoustics Laboratory, 20B-052, Massachusetts Institute of Technology, Cambridge 39, Mass.

two-dimensional geometrical analysis. The two-dimensional method, however, is used by most of the designers. A great improvement would be made if a three-dimensional simplified descriptive geometrical method could be developed.

We have learned from Mr. Moir (see the preceding paper in this JOURNAL) of a method of studying the echoes in an existing building, but it would certainly also be nice to design an "instrument" for *predicting* the echoes, so they can be avoided from the time the building is in design.

The shapes of the modern theaters are in most cases of the usual type, narrow in the front and wider in the rear part, with a strongly absorbing rear wall. In only two cases I know of, have modern theaters been built without absorption on the rear wall. In one of them, absorption material was put up later in order to reduce disturbing reflections from the wall. The other case seems to have come out all right. It is the Alexandra Theater in Copenhagen, the rear wall of which was made sloping, in order to reflect the sound down to the rear seats. The side walls in this theater are also tilted, 7 degrees inward, the reason being to get some of the sound reflected down to the floor instead of letting it go to the rear wall, where it might give rise to disturbing echoes of some kind. The reverberation time in this theater is rather high, around 1.7 sec at 500 cycles, which is much higher than the average. A theater of the same shape but without balcony has been built in Stockholm, Sweden, but there absorption material was introduced both on the side walls and on the rear wall. Unfortunately, I have had the pleasure of visiting only the theater in Sweden, so I cannot make any statement of comparison. The tilted side walls have been used also for ordinary auditoriums; for example, the new physics lecture hall in Gothenburg.

In regard to the shape of the room, it might be mentioned that the type of floor which is lowest in the middle is beginning to be used in motion picture theaters in Scandinavia. Because it is lowest in the middle and rises toward the rear and front parts of the theater, it is possible to eliminate some of the "neck-strain" for the spectators in the front seats and to make visual obstruction small and almost equal at all parts of the theater.

Even if the volume per seat is kept low, and plane parallel walls, etc., are avoided to get good diffusion, a certain amount of absorbing material of some kind is usually introduced to keep the reverberation time low. As a basic criterion (besides that of uniform and sufficient sound intensity at all seats), we believe that the sound reproduced in the theater should be of the same quality as where the scene was taken, assuming that the sound on the film has the correct reverberation time to begin with. This criterion can, of course, be fulfilled only if the reverberation time is sufficiently low. This criterion is directly connected to the problem of reverberation time for electrically-coupled rooms.

The problem is to find the resulting reverberation time in the reproduction room of a sound which is picked up in a sending room. The sending room and the reproduction room generally have different reverberation times. The combined reverberation time is approximately equal to the longer of the two reverberation times of the sending and reproduction rooms. This is true if the separate reverberation times are not too close. If they are equal, the combined reverberation time in the reproduction room is 20% higher. It may be mentioned that the reverberation curve is not an exponential function in this case, and that the reverberation time is taken as the time required for the intensity to reduce 60 db. If the reverberation is based on, for example, 40 db, the difference mentioned above is larger than 20% which is also the case if the slope of the curve is taken as a base for the definition of reverberation time.

As an illustration, let us assume that a scene has been taken out of doors, where the reverberation time is small. When reproducing this, we cannot get shorter reverberation time than that of the theater, which for low frequencies might go up to about 3 sec. The coordination between reverberation time and the picture shown on the screen under such conditions cannot be satisfactory. I don't know of any systematic studies of this problem, but it would certainly be interesting to learn how we react for a bad consistency of that kind.

The advantage of a short reverberation time is not limited to satisfying the criterion mentioned. There are other advantages, for example, the possibility of obtaining well-defined "sound focus." That this is of importance is established by the results from the survey made by Mason and Moir. In some cases, the theaters were reported unsatisfactory because of the confusing feeling resulting from bad sound focus. Good sound focus might be rather difficult to obtain with a large amount of reverberant energy present. Furthermore, and this may be most important, the possibilities of obtaining disturbing echoes is much reduced. Since we know that it is very difficult to avoid them in the original design, using ordinary design rules, absorption seems to be the safest solution. Another advantage with high absorption is the improved reduction of noise, which I think is of importance.

In order to fulfill the criterion mentioned that the sound shall have the same quality as at the place where it was originally picked up, we must keep the reverberation time almost independent of frequency. By proper choice of absorbers it should be possible to obtain a rather straight characteristic.

The absorption material which is used in the theaters in Scandinavia is mainly thin-panel absorbers for low frequencies and some kind of porous absorber for the highs. The most usual type of porous absorber is tiles of wood fiber. Among the fireproof tiles can be mentioned asbestos and different kinds of gypsum constructions. A very nice method used frequently is asbestos spray. This is very expensive in our country compared with, for example, tiles of wood fiber. There is, however, a great demand for fireproof tiles and I am surprised that tiles of glass fiber, such as used in this country, have not yet been manufactured in Scandinavia. At the present time, when glass or rock wool is used, it is always in connection with perforated facings.

Discussion on the Forum on Motion Picture Theater Acoustics

Members of Discussion Panel:

LEO L. BERANEK (Moderator), Massachusetts Institute of Technology
JOHN E. VOLKMAN, RCA Victor
JAMES Y. DUNBAR, William J. Scully, Inc.
RICHARD H. BOLT, Massachusetts Institute of Technology
EDWARD J. CONTENT, Acoustical Consultant
A. W. COLLEDGE, Western Electric Company
EDWARD S. SEELEY, Altec Service Corporation
HARRY F. OLSON, RCA Laboratories

Dr. Beranek: To start the discussion, I will call on those at the table, starting at the end:

A. W. Colledge: Not having done any acoustic design work since the late '30's, I can take a more academic and historical viewpoint than some others here.

If this problem were simply the acoustical design of an auditorium, and specifically the theater auditorium, there wouldn't be the difference of opinion that may show up as this discussion gets under way. Our subject might better be defined as how to achieve excellently reproduced speech and music in a theater auditorium with the restrictions imposed on us. We reproduce in the theater both speech and music from a sound track that reflects the acoustics of the sound stage and the electrical characteristics of the recording system, and is affected by the reproducing equipment in the theater.

Also, in talking of the reverberation time of an auditorium, we will have to take into account the "apparent" reverberation time. As an illustration of my point: if you take a long narrow room lined with tile, you will find that the acoustics are terrible. If you place loudspeakers in the ceiling, pointing down and operating at low levels, you will get quite good reproduction as far as the people seated in that room are concerned. So there is something, if you will, in "apparent" reverberation time.

Before the discussion gets under way, I will stick my chin out and say that I feel we, as a group, have gone too far in trying to get too much "liveness" in an auditorium, that is, high reverberation time. I believe there are reasons for that, and probably I can point out some of them.

Initially, our job was only to get reproducing equipment into the theaters. Then acoustics reared its ugly head, and several of the larger companies formed acoustic groups. There wasn't very much known about acoustics before then, and what was known was derived primarily from results obtained in a few theaters. But we suddenly had a few thousand theaters thrown at us.

I still remember that those theaters, which are now considered overly dead,

were the ones where the customers could sit in any seat, relax and understand the performance; and the problem of placing horns was quite simple. However, these theaters were few in number, the large majority were acoustically fair to poor, and something had to be done to them to obtain good reproduction. The only thing to do was to place absorbing material on the rear and side walls and rear ceiling, and you would get at least satisfactory results.

About that time, we suggested tentative reverberation standards and started experimenting with means of measuring reverberation times. We found that the calculated values did not always agree with the measured times. Also, we became conscious of the effects of shape and low-frequency absorption. We found that in theaters that had wood paneling we didn't get the "booming" effect of a high amount of low-frequency reverberation, but instead got quite desirable sound. We began to suspect that a flat reverberation-frequency characteristic was something we would prefer.

But as we got into the shape factors, we began to feel—and I am afraid some hoped—that with nonparallel and broken-up surfaces, we could stand greater reverberation times. Also, I think too much emphasis was placed upon the quality of music reproduction. It is generally agreed that the optimum reverberation times for speech and for music are quite far apart. And something of which we have often lost sight is that about 80% or 90% of all sound coming out of Hollywood is speech.

It seems to me, therefore, that in our consideration of the design of the acoustics of a motion picture auditorium we should be guided by this fact in the compromise that we must make in the reverberation time. We must make this compromise to get good speech reproduction. I feel that, for those theaters that hit such an average, the music reproduction is not at all objectionable.

How far we have gone, I do not know. I am ashamed to say that I can't quote the Academy figures. I do remember, in one theater, using a value of reverberation time of about 1 sec for a volume of 100,000 cu ft. I admit it was not "live," but I don't think it was dead. We never had any complaints on sound quality!

If we have gone too far toward high reverberation times, I think that, as I said before, one of the reasons was the hope that complete breakup of surfaces would allow us to tolerate greater "liveness." It is possible, too, that during the period when higher reverberation times came into use, we made a lot of measurements using a number of horns which were quite directional in the frequency range above several thousand cycles. That is why I introduced the term "apparent liveness." I think it is quite obvious that if we placed the reproducing horns high above the stage and pointed them down into the audience, we had a minimum of side-wall reflections, no ceiling reflections, and those reflections we did get were relatively short. Under these circumstances, we judged that we could tolerate more "liveness." Subsequent to those tests, multiple horns were introduced to give us a dispersion of high frequencies, and the side walls are now back in the picture. There is now a suspicion, at least, that we have gone too far down the trail of "liveness."

Dr. Richard H. Bolt: I am very glad that Art Colledge took the academic point of view. That leaves me free to be quite unacademic. I find that I am in substantial agreement with virtually every point that has been made. Perhaps this isn't a healthy situation for a discussion. I would like, therefore, to pick up just two or three of the points which Mr. Moir and Mr. Ingard have made, and toss out a few comments regarding them.

This question of the first 30-db decay being important is certainly logical, especially when you take Mr. Colledge's

statement that some 90% of footage is speech, and when you add to that the fact that the speech articulation area has a 30-db dynamic range. In no case can a speech component interfere with intelligibility after it has decayed 30-db. Some number such as this seems to make sense in the case of speech. Perhaps it also makes sense in the case of music, though we aren't yet established on a music-articulation engineering curve, as we are on speech intelligibility.

Another interesting point is that this curve of the combined reverberation from two rooms of equal or different reverberation times is quite suggestive. It starts out, as Mr. Ingard pointed out, with a rather small slope, smaller than the final slope.

Now, if again we take just the first 20 or 30 db of the decay, obviously we are talking about a longer "reverberation time," as Mr. Moir implied, than the value defined for 60-db decay.

I believe others have experienced what we have, namely, that when viewing a movie playback, which was originally recorded under one condition of reverberation and played back in a room with a different reverberation time, and when you know roughly what these two reverberation times are, and go through the calculation which Mr. Ingard suggested, you usually get the impression that the combined reverberation is a good bit higher than would be expected from the simple calculation of the combined reverberation from two coupled rooms. Many times it seems more than 20% higher. This feeling, I think, is associated with the first part of the curve. These things all seem to make sense.

I did have one question I wanted to ask Mr. Colledge. When he was discussing the low-level multiple loudspeaker system and mentioned that he got good reproduction, I presume he was referring to the good speech intelligibility, and not necessarily good presence.

Mr. Colledge: That is right.

Dr. Bolt: One of Mr. Moir's points was an interesting one: that there should be no sharp changes in acoustic impedance as you go down the hall. Intuitively, this certainly seems reasonable to me, but I don't quite visualize it in a quantitative way, and I wonder if you have further comments to explain just what you meant? Also, I have another question: You suggest no proscenium arch, and I wonder what led you to make that suggestion.

Also, I would like to support the statements and implications of both Mr. Moir and Mr. Ingard, that the question of proportions for relatively large theaters is probably more a matter of design and pleasing proportions, than of achieving some of the other factors we are looking for. Of course, if with proportions of the "recommended" type we can do a better job of distribution or of avoiding too long delayed echoes, that is fine. The point I wish to bring out here is that in rooms of more than 10,000 or 20,000 cu ft, it does not make sense to talk about the room proportions as providing a smoother distribution of normal frequencies. At low frequencies, in rooms of below 10,000 or 20,000 cu ft, and in small, strictly rectangular rooms, this has meaning. But it is hard to see how it has importance in rooms of 100,000 cu ft.

I would like to conclude with a thought I picked up when I referred back to "home base" on this question of acoustics. That is a healthy thing to do, occasionally: to forget about technical details and check with a somewhat impartial observer: my severest critic who has accompanied me to many theaters. I asked what she thought of the acoustics in a particular theater which I had a hand in designing. She had only one comment.

I might point out that her special interest was dramatics. She taught it, and acted it a good bit, and was quite familiar with the stage. She said, "Don't you realize that movie technique is different from the legitimate theater technique! A good actor on the stage times his speeches to the audience reaction. Now,

if he finds that a certain punch-line is drawing an unusual laugh, he waits for the laughter to die down, and then goes on with his next speech. On the other hand, if you try, in the movies, to design the sequences for the most enthusiastic audience, you will occasionally get a dud of an audience and there will be some gaping holes in the speech. So you have to compromise." She said, "It is true that to some extent this question of audience reaction is built into good movie dialogue, generally by having the punch-line followed by something unimportant. But this isn't carried out 100% in movie technique."

Now, this suggests that audience noise is a good deal more important in a movie theater than in a legitimate theater. I support the thought that, by reducing reverberation time, we gain on this point of noise reduction, as well as on several others that have been brought out.

However, I am not quite convinced that zero reverberation would be good. So far as the quantity, or the magnitude, of reverberation time is concerned, we will agree that combining two rooms produces some such predictable reverberation time. But suppose you are sitting in a dead hall and looking at a picture which is in a reverberant space, so that you expect a lot of reverberation. Maybe it is a politician in a huge convention hall, giving an address, and you record a lot of reverberation. But, if the film or sound is reproduced in the nonreverberant room, all of that reverberant sound is beaming at you from one point. Even though the recorded reverberation time is that which you expect, the effect of that reverberant sound, all coming from one point, is not necessarily the same as if the reverberant sound enveloped you completely.

So you have this conflict, that, for several reasons, we apparently want lower reverberation times than we are used to, though I don't think we want it at zero. Perhaps we should get our absorption by highly concentrated, high-absorption areas, leaving some reflective surfaces all around the room. Then when reverberant sound comes over the sound system, we can feel that some of it is indeed around us, and yet keep the reverberation time low enough for other requirements.

Dr. Beranek: I think we should have Mr. Dunbar speak now and save Dr. Bolt's questions until later.

J. Y. Dunbar: Although much is already known about the simple fundamentals of the acoustics of theaters, I have, during the last six months, encountered a number of theaters and auditoriums, designed by well-known architects, that hark back to exactly what we are sitting under here—the curved ceilings and concave back walls. There is no reason for such design in this country because we have no fire regulations that require it. Theaters are still being as badly designed, acoustically, as possible. Recently, I ran into one that seemed to be deliberately misdesigned. The curvature was exactly right to focus the sound into the middle of the audience. [Laughter] I have also seen theaters in which the balcony extended so far out and so deep that the absorption underneath it made it impossible to hear in the back, even though there was no acoustical treatment under the balcony.

I very much appreciate Mr. Moir's attempt here to evaluate scientifically the contribution of a hall to aesthetics, that is, to the resonance and the timbre of sounds produced in it. I do think that for best response to music, particularly, the hall should contribute a certain amount of quality to what is played in it. I believe that the hall itself is an extension of the musical instruments in the hall, and that it adds to the timbre and resonance of the movie. It is rather a difficult thing to evaluate, but I think it would be a very good approach to try to find out what that contribution is.

I would further like to accentuate Mr. Colledge's plea for deader halls or thea-

ters. In the first place, it means that reverberation is changed very little by changing audiences. The lower the reverberation is when the theater is empty, the less it is going to be changed by adding an audience to it; but if you start out with a high reverberation time, and some of these tests may have been made either in empty halls or partly-occupied halls, you get an entirely different response than you would if you had a full auditorium. If the change in reverberation time is very great, you have a hall that is very bad when there are few people in it, say, at the first show, and excellent at the next show. You get a minimum change in reverberation time with occupancy when perforated seat bottoms are used for sound absorption, or when heavily upholstered seats are used, as in a few of the smaller theaters around the country.

There is one playhouse in New Jersey where the seats are extremely well padded. That is an excellent idea because you can take a nap if the show is dull. [Laughter] In that theater the reverberation is the same whether the house is full or empty.

Another important consideration is the number of cubic feet per person. This number is a function of the number of people entertaining or talking. For example, the smoker in a Pullman car is roughly 6 by 8 feet in area and is a beautiful setting for the raconteur. In a lecture hall that holds up to 50 people, you must provide 70 to 80 cu ft per person. For larger-volume rooms the number of cu ft per person becomes much larger.

The other question is the matter of height. If you increase the volume by increasing the height of the room, you aggravate your reverberation problem; and if you make it too low, then the sound doesn't distribute well in the back and you get peculiar reverberation effects. The ratios of width to length and height of a room are a function of custom that has come down through the ages from the development of public buildings that were more or less pleasing in shape and usefulness. Hence, when we do something peculiar, it shows up immediately.

Edward S. Seeley: I would like to emphasize that we are here challenging the existing recommendations of optimum reverberation time. So far as I know, this is the first time that the established published recommendations have been challenged—certainly the first time since the war, and perhaps since some little time before the war.

I believe that out of this meeting will come a careful reconsideration of the whole question of reverberation time. Certainly it will have to be based upon a great deal of experienced discussion and comment from a large cross section of people interested in this subject. Nothing is going to be settled here this afternoon, I am sure, except that some of us will have convictions renewed, and a few may leave with convictions shaken. I have a feeling that although thinking in architectural acoustics has expanded rapidly in a lot of byways, it is still very strongly dominated by some of the very early conclusions.

One of them, which I will come back to in a moment, is the definition of reverberation time, which has existed unchanged for many years, but which is now being slightly restated. Although people haven't been following the concept of 60 db of decay too closely, they have kept their eyes on that earlier definition, more or less. In most cases, you can't measure more than 30 db of decay outside of the laboratory, and it is doubtful that the ear hears more than the first. I will come back to that in a moment.

Another thing is that the original establishment of optimum reverberation time for rooms was based on unamplified speech. The reverberation time *per se* hurts articulation. However, if the reverberation time of a room is very low and the room is very large, the level of speech will be so low that unamplified speech will be unintelligible in the presence of audience background noise.

Nowadays, we have audio amplifying systems in every large hall, and I question seriously whether this change in the situation has been adequately reflected in practice and in the recommended standards.

I might observe that my own connection is with theaters that are operating—thousands of them, of all kinds. We do not design or treat theaters, but we receive their complaints of bad quality.

I would emphasize that complaints are very rare where the house is too dead. Most of the complaints of poor clarity arise in houses which are on the reverberant side, assuming, of course, that the sound system is not at fault.

I would like to congratulate Mr. Moir and his colleagues in reducing to an engineering basis some of the things we have tried to handle by intuition, "golden ear" experting.

Some of Mr. Moir's illustrations remind me of the significance of direct sound. We recognize the importance of direct sound in theaters, but very little may be found on this subject in the acoustics books. In the theater, as one moves out of the area covered by the speaker—the direct sound area—quality drops rapidly, although the reverberation time is much the same. The ratio of direct to reverberant sound is tremendously important when we are listening to speech.

I am happy that a question has been raised concerning the extent of decay to be represented in an appraisal of the reverberation time. In 1940 and 1941 I tried to sell the idea that we were too interested in the lower end of a decay characteristic. I would like to go further than the gentleman who preceded me and suggest that conclusions be based on the first 14 to 24 db of decay. I would be willing to consider favorably even less than 14 db as I question that trouble is very often experienced with sound that has decayed further than that. I have no evidence to back that up, other than personal observation.

Dr. H. F. Olson: From the foregoing papers and the discussion, it seems that the ratio of direct to reflected sound appears to be the important characteristic in sound motion picture theaters. Fundamentally, this becomes what we might call the effective reverberation, or as Mr. Colledge said, the apparent reverberation.

There appear to be several ways of obtaining a suitable effective reverberation through proper design of the theater. Of course, the shape of the theater is involved, and that is a very complex subject, as has been discussed here this afternoon. The effective reverberation also depends upon the reverberation time of the theater as well as other effects which are more complex and difficult to take into account.

A proper effective reverberation can also be obtained by suitably designed reproducing equipment. For example, the effective reverberation depends upon the directivity pattern of the loudspeakers and the shape of the response-frequency characteristic. Thus, some engineers may work on the theater, others on the equipment, yet both obtain almost the same end results. It is quite true that you can have a very poor theater, yet can obtain very good sound reproduction by the use of suitable equipment. On the other hand, you can have only fair equipment, but a very good theater, and obtain very good sound reproduction.

There is also one other type of theater which is very interesting, namely, the drive-in theater where the reverberation time is very low. In the drive-in theater, the accepted method is to use a separate loudspeaker for each automobile. The reverberation time of an automobile is very low. This system has brought many comments from listeners stating that they feel this type of reproduction is superior to that of the conventional enclosed theater. We have had similar comments from people about automobile radio receivers. Since the war, automobile radios have been improved tre-

mendously, and people tell us that the reproduction in automobiles is far superior to that which is obtained in the home. I believe that the improvement is due to both the characteristics of the receiver as well as the acoustical characteristics of the automobile itself.

From what we have heard today, it seems that the subject of reproduction of sound is still a pretty complex one!

John E. Volkman: I, too, have been very much impressed by the engineering phase of Mr. Moir's paper. It gives a much better way, I believe, of going into the theater and finding out about those acoustical problems which we all admit have been present, but which we haven't been able to analyze well. In a nutshell, I believe that much of the data he has shown emphasizes the fact that echo is as disturbing in the theater as is general reverberation.

What do Mr. Moir's results mean to the architect, and to the person who is going to build the theater? I think this forum emphasizes, as have a number of other forums, that there are still some very important acoustical problems that exist in theaters and that a lot of these problems are echo problems. These echoes arise from a curved rear wall, large expanses of flat areas, flutter echoes, and so on.

Of course, in the sound movie theater, we can eliminate a lot of the echo problems by speaker placement, and by making the speaker directional. If we can get the sound to travel directly to the audience without the beneficial aid of the side walls, so much the better. But no speakers have been designed yet which are so perfectly patterned that they deliver sound only to the audience.

In analyzing the sound arriving at the listener's ear, we have first the direct sound. Then we have the first and beneficial reflections. These are the ones that, as Mr. Moir indicated, come within the first 100 msec.

Beyond that time, come reflections which are, perhaps, second or third reflections. These are the disturbing echo reflections. After that there are the conglomerate reflections which we think of mostly as reverberant sound in the room.

The first 30 db of the decay portion of the curve concerns itself with those early reflections. In this country statements have been made that it is desirable to have the early part of the decay curve drop suddenly, and then the trailing-out reverberation will not be too disturbing from an articulation standpoint, but will add color to the overall sound.

I would like to make a comment also with regard to the reverberation as perceived by the ear when there is a high noise level. In industrial plants, we have observed that with the noise in the plants we are not conscious of reverberation in the overall system. The same applies in those types of systems that have the multiple-speaker arrangement, which Mr. Colledge mentioned. However, if you stop the machinery and then listen to the sound, the reverberation sounds terrific; but you are not conscious of it when there is intense noise. So I think we are all agreed that those last reflections that are more than 30 db down, are not of prime importance.

There has been some discussion as to whether our optimum reverberation time is right, too high or too low. I don't think we are going to change that very much. The ear will tolerate considerable variation, but it dislikes some of these disturbing echoes that get to the audience.

I think I agree with the other speakers that the shape factor—that is, the proportions—in the large room is not dictated so much by the acoustics as by other more general considerations of appearance, and so on, because the eigen tones [natural frequencies] and the room resonance are very close together, and are not predominant at the higher frequencies.

E. J. Content: I think we are up against the same old problem that we have been fighting for a number of years—what is high-quality reproduction? Frequency response, we know, is only one factor. There are many other factors in the electric system which have been pretty well licked by now, such as signal-to-noise ratios and distortion in the electrical circuits. Those, I think, we can discount and take out of the picture entirely. However, the acoustical distortions are the ones that we are more interested in, and they consist mainly of echoes and interference patterns.

Mr. Moir stated that the worst theater he had studied also had the best frequency characteristic. I am wondering what he meant when he said it had the best frequency characteristic. Do we know what frequency response the ear likes best to hear? I think it is high time that we or the Society of Motion Picture Engineers, or someone, begins some kind of studies in the psychology of ear-hearing to determine what the ear likes to hear.

You can have a flat loudspeaker in a relatively large auditorium, and may find it sounds perfect; but if you put that same reproducer in a small room, it sounds as though there are too many high frequencies in its output. That, of course, is a function of the attenuation of sound in the air. When you have a large auditorium, where the mean free path is large, you have much greater attenuation of the higher frequencies, especially in locations where the humidity is very low at times.

Now, let us go back to frequency response of a room. The frequency response, or frequency characteristic of the room is determined by the absorption of the different sounds by two means: one, by the acoustical surfaces; and the other, by the attenuation through the air. For a small theater to have the same response, much more absorption of the higher tones is needed than for a large theater. I am talking of the 1000-seat house, as against a 3500-seat one, because the length of a mean free path is much greater in the large house.

If the reflected tones from the room surfaces and the tones from the loudspeaker have been attenuated to such an extent that they don't represent the same true character of tone that the loudspeakers emit, naturally it is much more pleasant to listen to the loudspeakers without any reverberation. However, if the absorption of the theater can be adjusted so that the reflected tones give you the same response as the original sound, considerably more reverberation can be tolerated than otherwise. That is one reason why, when you get out of the beam of a loudspeaker, the tone goes to pieces. It is because the absorbing surfaces do not reflect the same tones that are cast upon them; otherwise, you would get the same tone color reproduced.

Dr. Beranek [after thanking the panel speakers]: Mr. Moir has, I think, at least three questions to answer. I have been keeping track of them. He is supposed to answer: Why no proscenium arch? Why no sharp changes in peaks? And what is the best sound system characteristic?

Mr. Moir: The first two questions really cover two aspects of the same problem, that of maintaining a smooth flow of sound energy along the hall. Experience in many cinemas has indicated that changes in sound level and sound quality are often associated with sharp changes in the cross section of the hall, of which two examples are the proscenium arch and the stadium-type of design. While no quantitative data on the adverse effects are available, a typical example could be quoted. A legitimate theater of modern design was the subject of serious criticism on the score of lack of intelligibility, until an apron stage extending forward of the proscenium arch and over the orchestra was constructed. As an ordinary member of the audience, the speaker had on many occasions noted the improvement

in intelligibility as an actor moved down stage past the proscenium arch.

Regarding the best sound system characteristic, I have checked my idea of "best" in many British theaters and found that it did not differ appreciably from the published American data. In particular, a roll-off above 2.5 to 3 kc has seemed essential for acceptability. Anything flat to 5 or 6 kc has been found intolerable.

Dr. Beranek: Are there other questions for Mr. Moir or other discussion?

Mr. Volkman: We have made somewhat similar measurements in the overall acoustic response. Some of the installations that sound good were measured by the warble-frequency method. Incidentally, one of the nice features of Mr. Moir's method of measurement is that it simulates the short-pulse effect of speech.

Going back to this response, we have found that a flat response up to 3200 cycles which tapers off about 12 db per octave is preferred. In recording, they more or less raise the overall acoustic response at the top end.

Mr. Colledge: It is pretty close to the Academy curve. Has your experience indicated that for typical public address systems' sound reinforcement, you can use more highs?

Mr. Volkman: Yes.

Mr. Colledge: I find that on stereophonic systems I can run to 1000, and then start tapering off.

Mr. Moir: The experience we had confirms your experience there.

Mr. Volkman: But this does not show, of course, what your method shows, that your direct response may be rising, and your reflected response falling.

Mr. Moir: Our work on frequency characteristics has given results of the same kind.

Anon: Mr. Seeley pointed out that we are here challenging the accepted techniques of theater design. In order to make a satisfactory challenge, we must cumulate a lot more experience. It seems worth while, therefore, to disseminate among the group here, at least, some of the details of technique that you have worked out, so that we can benefit in getting experience of our own. A question that occurs to me is how do you avoid the transient that normally occurs when you turn a signal on and off? Do you have some control over that?

Mr. Moir: It is a problem, but a double contact switch can be used to close the circuit through a resistance, and then to short out the resistance.

Anon: Do you find that this mechanical arrangement is satisfactory?

Mr. Moir: We have gone no further than trying this arrangement. There are two or three other more important problems on which we are doing some work.

Anon: On your pictures, I noticed there was no peak—no initial pulse. Was that because the picture didn't show it, or was it because it wasn't there?

Mr. Moir: Do you mean the click?

Anon: Yes.

Mr. Moir: No, there was no serious click on the picture. There is no reason why it should be above the noise level in the theater. If you listen to the pulse, there is a slight click, but it does not appear to be appreciable. We think that it can be neglected.

Anon: Do you have any idea about what could be used as a quantitative measure of the ratio of direct-to-reverberating sound? Would you integrate the area under the reverberation curve up to a certain value of time?

Mr. Moir: I don't really know. We haven't done enough work to make a definite statement. We haven't really had enough experience to formulate any definite proposals. That is a weakness of the position as it is at present. It needs to be figured, but just at the present time we are in a depression in England, and there is no money for development. It is regrettable.

Anon: One other question: Have you tried varying the frequency of the test oscillator, more or less continuously?

Mr. Moir: We have taken pictures of

pulses of tone over the whole frequency range.

Anon: What I meant was, do you get a continuous variation as the frequency is changed?

Mr. Moir: One of the methods we developed was to try to take frequency characteristics in a very short time, of the order of 0.1 or 0.2 sec, but it revealed nothing and we dropped it.

*Ben Schlanger:** As an architect, one point that bothers me today is that, in the case of a motion picture theater, we have a very special type of auditorium which is different from the theater, where there is simply no reinforcement, and also a theater where there might even be reinforcement, such as a public address system.

For many years, now, motion picture theaters have had sound reproduction that we might call commercially acceptable, but we are coming to a new age in motion picture theater experience, in which the dramatic impact is going to be the thing. In other words, we have to go beyond the point of what is just acceptable—on such aspects as audibility, intelligibility, and so on.

What it all boils down to is this: Is it possible for the acoustical color that is added by the room itself to be completely discounted so that whatever effect was made in the production could be delivered to the audience without coloration by the room?

Will a dual system of horns be effective—one set, which may be behind the screen, for the dialogue, where reverberation isn't important—and the other set scattered around the room where an effective reverberation is required to give, dramatically, the effect desired?

As architects, we have always been told by the acoustical engineers that the shape of the room and the amount of reverberation, and so forth, are important. I wonder if we aren't past that stage. I noted that Mr. Ingard said they are going to less than 5 in the relationship of the screen width to viewing distances. That is an important point. I can safely predict that is true. It is going to go far below 5. I think people are going to sit closer to the picture. The picture is going to dominate your field of vision.

I think we have a whole new set of principles to work on, because the motion picture is no longer the novelty, at least the sound motion picture, that it was 20 years ago. Today it is dramatic impact, size of picture and realistic delivery that have become important, because home television has become a real competitor.

I have been very much interested in what was delivered here. I think you are really making progress, but I feel you have to give prime consideration to the ultimate aim, and that is more effective delivery of both the visual and aural storytelling.

Mr. Moir: I think some of the engineers here might reply to these points better than I. I know of no method of giving you open-air experience in an enclosure, for various well-known reasons. I think you may be right when you say you should move along those lines, but I would like to tackle some of the problems that are easier than that.

Mr. Seeley: I feel that the relationship you found between frequency characteristic and quality is an effect and not a cause, possibly. You probably selected frequency characteristics most successful in the house, and then you later made measurements and found out what those characteristics were. It does not mean that the characteristic that slopes off quickly or remotely is a good one, but is something that reflects some characteristic or quality of the house.

Dr. Bolt: I don't believe that this point has been brought up as yet, but it certainly is an important one: the question of the proper adjustment of level in the theater. We had occasion recently

---

* Partner, Schlanger and Hoffberg, Theater Engineering and Architecture Consultants, 35 W. 53rd St., New York 19.

to make measurements continually during the performances in a theater at various points, not only to listen, but to overhear comments of people watching the show and the people who came out from the show. There was a relatively small level difference which separated good from bad.

In this particular case, when we were running around an 80- to 85-db average, the reactions expressed after the show indicated that that was too loud. We had control over the level in this theater during the performance. When we got it down to about a 60-db average on the speech, we were missing a good bit of the intelligibility. Then we heard a conversation behind us, where a girl and a boy who were enjoying the show, said, "Gee, can you hear that very well? Something must be wrong." That was at 60. Between 65 and 70 the level was satisfactory.

The significant thing that came out of measurement of this kind was that not more than 15 db separates pretty bad from pretty good. I wonder if this is the sort of experience found by the others?

Mr. Moir: Yes. The BBC published some figures on level preference tests. I have the papers in my bag and will show you the figures. They found, surprisingly, that the engineers preferred a higher level than the public, and older people preferred it slightly lower in level than young people.

Mr. Volkman: You described the one case where the listening conditions were good in some parts of the auditorium, and poor in other parts. How highly localized were the poor listening areas in the theater? Do you have some information on that?

The reason I ask is that we had a similar problem in the Radio City Music Hall about ten years ago when we used frequency pulses to measure the echo and help us locate the echo. We found it to be due to the columns supporting the mezzanines just at the rear of the orchestra seating area, and they had to be inclined forward. The total area affected by those columns was very minor, and the echo was only in the rear of the auditorium. When we inclined them, we got rid of it. How localized was that?

Mr. Moir: In that case, I showed a slide. It was over 4 seats.

*W. F. Jordan:** It has been said that the acoustics problem must be carried all the way through to the recording. If I recall correctly, back when sound pictures first started, the recording characteristics were changed in a very radical manner, in order to adapt the sound to the then existing theater conditions. Now, as architectural improvements are made, we are going to have to revise our original concept of a recording characteristic. In other words, the so-called Academy characteristic, a large rise in the high-frequency response, may have to be modified.

[Moderator Beranek adjourned the meeting.]

---

* Movietonews, 460 W. 54th St., New York 19, N.Y.

New American Standard

Sound Transmission of Theater Projection Screens, PH22.82, was developed by the Society's Sound Committee based on a war standard, Z52.44-1945. The specified transmission characteristics are in accord with most present-day theater screens of proven performance value.

The need for this standard was indicated by the occasional installation of screens with excessive transmission loss. Increasing the gain of the sound system as a compensation very often drives the amplifier into its nonlinear region and consequently produces excessive distortion.

American Standard for

Sound Transmission of Perforated Projection Screens

ASA
Reg. U. S. Pat. Off.

PH22.82-1951

*UDC 778.554.4

1. Sound Transmission Characteristics

1.1 The sound transmission characteristics of perforated projection screens shall be such that the attenuation at 6000 cycles, with respect to 1000 cycles, is not more than 2½ db and the attenuation at 10,000 cycles, with respect to 1000 cycles, is not more than 4 db. The regularity of response shall be such that there is no variation greater than ±2 db from a smooth curve at any frequency between 300 and 10,000 cycles. The general attenuation at and below 1000 cycles should be not greater than 1 db.

2. Method of Measurement

2.1 The sound transmission of the screen shall be measured by means of a loudspeaker, fed by an audio oscillator and amplifier, behind the screen, and a calibrated microphone, amplifier, and output meter in front of the screen. The loudspeaker shall be of the type normally used in motion picture theaters for the size of screen being tested, and shall be placed with its axis not less than 2 feet from an edge of the screen with its mouth parallel to and separated from the screen by 4 to 8 inches (center cell in the case of a curved-front multicellular horn). The microphone shall be located 10 to 12 feet in front of the screen and on the axis of the loudspeaker. The sound transmission of the screen at any frequency is then the difference in the sound level measured with the screen in place and with the screen removed.

2.2 Suitable precautions shall be taken to eliminate or minimize the effect of standing waves in the test room.

Approved July 17, 1951, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

70th Convention

Hollywood Roosevelt Hotel, Hollywood, Calif., October 15–19, 1951

Color Processes of motion picture photography and release printing now being introduced commercially are capturing the interest of all motion picture producers and film laboratories. Latest developments along these lines will be presented for the first time at one of the eleven convention sessions. Related to these current indications of progress in the field of "color" is the continuing work of the SMPTE Color Committee which will be reported upon by Chairman H. H. Duerr.

Color Aspects of television have been in the public eye recently and, in addition to popular concern for the future of commercial color television, there has been serious interest among technical people. Examples of the most pressing questions are requirements of studio conversion to color standards, and an estimate of those factors now apparent that will some day prove to have had a significant influence over long-term growth. Both will be discussed at length during another session, along with the description of a new system for reproducing a color television picture.

Magnetic Recording equipment newly developed for efficient re-recording of feature film sound as well as numerous improvements in equipment and production techniques will be reported upon over two technical sessions.

High-Speed Photography as a tool in aircraft, guided missile and ballistics research will be the subject of one convention session. Another will include papers on new developments in cameras and on sound recording as a data gathering process.

Stereo-Projection, much conjectured about, will be discussed, demonstrated and explained. This session which is certain to interest motion picture people widely is scheduled to include reports by two SMPTE engineering committees, one on Picture Flicker and one on Screen Brightness.

Chairman of the Pacific Coast Section, C. R. Daily, is also *Local Arrangements* Chairman for the fall convention. This latter title gives him the pre-convention responsibility for lining up the three sessions to be held away from the Hotel and for the general supervision of all arrangements except in connection with ladies' program, papers, motion picture short subjects, luncheon and banquet. He will keep an eye on:

Hotel Reservations and Transportation which Bill Kunzmann has assigned to Vaughn C. Shaner.

Projection Facilities, at all four meeting places, Hollywood Roosevelt Hotel Blossom Room, Academy Award Theater, Republic Studio Scoring Stage and Columbia Square. Emery Huse, Eastman Kodak Company, will provide the 16-mm arc equipment for use at the hotel. Members of Los Angeles Projectionists Local 150 will put the pictures on the screen.

Public Address equipment and the recorder used to take down technical discussion will be supplied by SMPTE headquarters and operation will be supervised by E. W. Templin, Westrex Corporation.

Engineering Activities

Color The Color Committee, under the Chairmanship of Dr. Duerr, met in New York in mid-June. Most of the Committee's work is done by Subcommittees; therefore the meeting opened with reports of Subcommittee Chairmen:

(a) Color Symposium Subcommittee: Lloyd Varden indicated that additional information is still required before editorial work on publication of all color-process data can begin. Both DuPont and Ansco have proferred assistance along

these lines, and a draft of the introductory report should be ready shortly.

(b) Subcommittee on Projection Light Sources and Screens for Color Film: Ronald Bingham discussed the status of the several projects. A good deal of information has been acquired on the effect of theater projection practices upon color quality and a report will soon be available. Characteristics of projection screens are also under study and a report is now being prepared by Mr. Gillon.

(c) Subcommittee on Spectral Energy Distribution of Photographic Illuminants: Monroe Sweet stated that the Subcommittee had met on March 9, 1951, and had agreed that the aim of this group was "to prepare a report of the history, present status and, if possible, a proposal for improved methods of determining, and technology for specifying, the spectral energy distribution of photographic illuminants, particularly those used for motion picture photography." While in an early stage, progress is being made on this project.

Dr. Duerr then reported that a request had been received to standardize the color temperature for color films used with tungsten light sources. The technical and commercial aspects of this problem were discussed and it was agreed that this matter properly belongs within the scope of the Motion Picture Studio Lighting Committee as far as motion picture technique is concerned, and within the scope of the ASA Sectional Committee, PH22, as far as the amateur and professional color films are concerned. The Color Committee would provide assistance to the Studio Lighting Committee if needed.

The Committee's part in the Society's Glossary project was the last point on the agenda. After much discussion, it was agreed to set up a preliminary subcommittee whose function would be merely to determine which terms should be included in the Glossary. When this is completed a more formal committee could be established to work on the definition of terms.

Laboratory Practice At its last meeting during the 69th Convention in New York, the Laboratory Practice Committee took definite action on two projects:

1. A Subcommittee to initiate a standard on laboratory review-room screen brightness is to be formed under the chairmanship of Edward Cantor.

2. It was agreed to ballot the entire Committee on the "Proposed American Standard for 16-Mm Optical Printer Aperture for Enlargement Printing to 35-Mm." Gordon Chambers was commended by the group for his efforts in preparing the recommendations upon which the proposal is based. The ballot is now almost completed and in all likelihood will be approved and forwarded to the Standards Committee.

Screen Brightness In accordance with ASA's procedure of periodically reviewing American Standards, the Screen Brightness Committee is now taking a letter ballot on "Review of American Standard Z22.39-1944, Screen Brightness for 35-Mm Motion Pictures." The Standard, as presently worded, applies to all theaters. Outdoor theaters rarely achieve the minimum value of screen brightness as set by the Standard, and so as a practical matter there has been some talk of limiting the Standard to indoor theaters. This question is included in the letter ballot.

Standards For the last several months the Standards Committee has been balloting on a whole series of proposals; some, on the question of the approval of preliminary publication and others, whose preliminary consideration has been completed, on the question of submitting to ASA for processing as an American Standard. These are:

Preliminary Publication

Proposed Standard for Aperture Calibration of Motion Picture Lenses.

Submission to ASA

1. Dimensions for Projection Lamps—Medium Prefocus Ring Double-Contact Base-Up Type for 16- & 8-Mm Motion Picture Projectors, PH22.84.
2. Dimensions for Projection Lamps—Medium Prefocus Base-Down Type for 16- & 8-Mm Motion Picture Projectors, PH22.85.

3. Splices for 1 6-Mm Motion Picture Films for Projection, PH22.24.
4. Splices for 8-Mm Motion Picture Film, PH22.77.

Recently Approved

Preliminary Publication—Proposed Standard for Cutting & Perforating Dimensions for 35-Mm Film (to be published in a forthcoming issue).

Submission to ASA—Edge Numbering of 16-Mm Motion Picture Film, PH22.83, and 16-Mm Motion Picture Projection Reels, PH22.11.

Television Studio Lighting The Television Studio Lighting Committee met on June 20th in New York City. Unfortunately, the attendance was so small that it was impossible to make decisions representative of the thinking of a cross section of the television industry. The Chairman, Mr. Richard Blount, noted that while it might be difficult for those members outside of New York to attend meetings, he would welcome their written comments which would be of considerable value in directing the thoughts of the Committee.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1950 **Membership Directory.**

Honorary (**H**) Fellow (**F**) Active (**M**) Associate (**A**) Student (**S**)

Aye, Thomas L., Radio Engineer, Henry J. Geist & Associates, Inc. **Mail:** 42 Middle Neck Rd., Roslyn, Long Island, N.Y. (**A**)

Barstow, John M., Telephone Engineer, Bell Telephone Laboratories. **Mail:** 105 Intervale Rd., Mountain Lakes, N.J. (**M**)

Barz, Helmut, Head, Rawstock and Printing, High Commissioner for Germany. **Mail:** Astallerstr. 15, Muenchen, Germany. (**M**)

Bhate, Arvind G., Development Engineer, National Carbon Co. (India), Ltd., P.O. Box 2170, Calcutta 1, West Bengal. (**M**)

Brown, Ilo M., Chief Engineer, The Ballantyne Co. **Mail:** 1707 Davenport St., Omaha, Nebr. (**M**)

Chodkowski, Stanley, New Inst. for Film and Television. **Mail:** 19 Goodyear Ave., Buffalo 11, N.Y. (**S**)

Chyka, George W., Motion Picture Cameraman, KOTV—Cameron Television. **Mail:** 1320 S. Boulder, Tulsa, Okla. (**A**)

Cooper, Donald H., Engineer-In-Charge, National Broadcasting Co. **Mail:** 14 E. Mason Ave., Alexandria, Va. (**A**)

Dickinson, Robert V. C., Recording Engineer, Telescriptions, Inc. **Mail:** Roome Rd., Towaco, N.J. (**A**)

Fields, Louis, Photographic Technician, Institute for Medical Research. **Mail:** 4024 Stone Canyon, Sherman Oaks, Calif. (**A**)

Filipowsky, Richard F. J., Professor of Electronics, Head of Faculty, Madras Institute of Technology (MIT India), Chromepet, Chingelput Dt., So. India(**A**)

Frierson, Leland G., Vice-President, Ruthrauff & Ryan, Inc. **Mail:** 108 E. 86 St., New York 28, N.Y. (**M**)

Frisbie, H. E., District Service Manager, RCA Service Co. **Mail:** 9215 Fernhill, Parma, Ohio. (**M**)

Geist, Henry J., Sales Engineer & Consultant, Henry J. Geist & Associates, Inc. **Mail:** 196—5th St., Stamford, Conn. (**M**)

Glasser, Donald W., Photographic & Reproduction Technician, Westinghouse Research Laboratories. **Mail:** 853 Inwood St., Pittsburgh 8, Pa. (**A**)

Haraughty, Lois E., Chemist, Eastman Kodak Co., 6706 Santa Monica Blvd., Hollywood, Calif. (**A**)

Hayden, Edward J., Chief Electrician, Ace Film Laboratories, Inc. **Mail:** 120 Linwood Ave., Bellmore, Long Island, N.Y. (**A**)

Heidt, Horace, Producer, Director, Actor. **Mail:** 14155 Magnolia Blvd., Van Nuys, Calif. (**M**)

Kantrowitz, Philip, Electronics Engineering Research Assistant, Microwave Research Laboratories. **Mail:** 2435 Frisby Ave., Bronx 61, N.Y. (**A**)

Kapur, Jit L., University of Southern California. **Mail:** 1023 W. 36 St., Los Angeles, Calif. (**S**)

Lankester, Christopher H., Technical Supervisor, United Nations. **Mail:** 144-79 Grand Central Pkwy., Jamaica 2, N.Y. (**M**)

LaSala, Frank A., Foreman, Cameraflex Corp. **Mail:** 185 Forbell St., Brooklyn, N.Y. **(A)**

Madsen, Erik R., Chief Engineer, Bang & Olufsen Aktieselskab. **Mail:** Gimsinghøje, Struer, Denmark. **(M)**

Mayer, Allan, Engineer, General Precision Laboratory. **Mail:** 132 Huntville Rd., Katonah, N.Y. **(M)**

Mayer, George H., Lighting Carbon Specialist, National Carbon Div. **Mail:** 6207 Park Lane, Dallas, Tex. **(M)**

Nash, Charles Kevin, University of Southern California. **Mail:** 800 Sunset Ave., Venice, Calif. **(S)**

Pieroth, John Phillip, Jr., Photographer. **Mail:** 1609 Peach Court, Seattle, Wash. **(A)**

Richman, Donald, Television Engineer, Hazeltine Corp. **Mail:** 64-25F 186 Lane, Fresh Meadows, N.Y. **(M)**

Riebel, Fred, III, Supervisor, Motion Picture Bureau, AEtna Life Affiliated Companies. **Mail:** 151 Farmington Ave., Hartford, Conn. **(M)**

Rothschild, Richard S., Engineer, Allen B. Du Mont Laboratories, Inc. **Mail:** 1165 Park Ave., New York 28, N.Y. **(A)**

Schwartz, Morton, Film Recording, RCA Victor Div. **Mail:** 698 West End Ave., New York 25, N.Y. **(A)**

Sheldon, Stewart, President, Sheldon Theater Supply. **Mail:** 1415 Amberly Dr., Dayton, Ohio. **(M)**

Sims, John M., Commercial Manager, Motion Picture Equipment, General Precision Laboratory, Inc. **Mail:** Manville La., Pleasantville, N.Y. **(M)**

Spiller, Gino, University of Southern California. **Mail:** 713¾ W. 35 Pl., Los Angeles 7, Calif. **(S)**

Tall, Joel, Audio Engineer, Tape Editor, Columbia Broadcasting System. **Mail:** 1594 Unionport Rd., New York 62, N.Y. **(A)**

Tohill, James C., Quality Control Analyst, Du-Art Film Laboratories, Inc. **Mail:** 37–42 64 St., Woodside, Long Island, N.Y. **(M)**

Torp, Richard V., Photographer & Color Technician, Technicolor Motion Picture Corp., Research Dept., 6311 Romaine, Hollywood 38, Calif. **(A)**

Wentker, Fred W., District Service Manager (Chicago District), RCA Service Co. **Mail:** 1505 Oak Ave., Evanston, Ill. **(M)**

White, Reginald A., Engineer, General Precision Laboratory, Inc. **Mail:** 94 Park Rd., Deepwood, Chappaqua, N.Y. **(A)**

CHANGE OF GRADE

Ballantyne, Robert S., President, Ballantyne Co. **Mail:** 1707 Davenport St., Omaha, Nebr. **(A)** to **(M)**

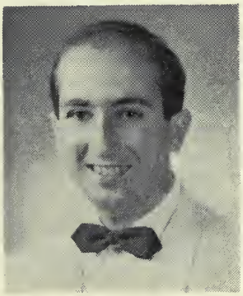
Mitchell, Wayne, Photography Instructor, Cinematographer, Audio-Visual Center, Miami University, Oxford, Ohio. **(S)** to **(A)**

Montague, Henry B., Projection Engineer, EUCOM Motion Picture Service, Maintenance & Supply Section, APO 807, c/o Postmaster, New York, N.Y. **(A)** to **(M)**

DECEASED

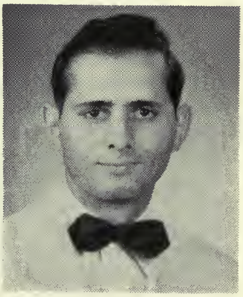
Hornstein, Joe, President, Joe Hornstein, Inc., 630 Ninth Ave., New York 19, N.Y. **(A)**

Newell, David A., Recording Supervisor, Samuel Goldwyn Studios. **Mail:** 1156 N. Poinsettia Pl., Hollywood 46, Calif. **(M)**



Donald Stern

Arthur Schneider



Donald Stern and Arthur Schneider in the early spring were elected next year's Chairman and Secretary-Treasurer, respectively, of the Society's Student Chapter at the University of Southern California. Photos are by courtesy of University Photographer, University of Southern California.

Carl Louis Gregory

The full and active life of Carl Louis Gregory, pioneer cinematographer, came to an end at the age of 68, last March in Van Nuys, Calif., after a year's illness of arteriosclerosis.

The man who was to receive many honors, be granted many patents, to teach and lecture widely, to pioneer in many parts of the motion picture field, was born in Walnut, Kan., in 1882. At the age of 11 he was making his own first camera from a cigar box and spectacle lenses. He entered Ohio State University in 1899, became a graduate pharmacist in 1902 and was graduated in 1904 with a B.Sc. in Chemistry. He earned money for his college courses by doing the photographic work for the college annual and biological photography for the medical and veterinary colleges.

After college began a career which for many years was to bring some new activity every year, sometimes with every change of season:

In mid-1904 he joined the Official Photographic Dept. of the Louisiana Purchase Exposition and was in charge of various sections including one where up to 1200 individual portraits were taken in a day, the airdrome section with airship, balloon and aerostatic work for newspapers and publicity, and the Quick Post Card Galleries which took photos and finished them in seven minutes.

In 1905 he was taking views for post card and commercial reproductions in the Southwest and Old Mexico, with a studio at Monterrey, Nuevo Leon, Mexico. In the spring of 1906 he had a commercial photography gallery at San Antonio, Texas, in conjunction with the Mills Engraving Co., and was making wet-plate line and halftone negatives for Mills. During the summer of 1906 he was official photographer for Manitou & Pikes Peak Ry. That winter he was in charge of the photographic Laboratory of Dodd-Rogers Co., Cleveland, Ohio, doing amateur finishing, blue printing and commercial photography.

In the spring of 1907 he was appointed photographer with the U.S. Geological Survey, doing chiefly wet-plate work but also lens and shutter testing and photomicrographic work under polarized light. In 1908 he transferred to the U.S. Reclamation Service, having first to do with everything in the making and exhibition of lantern slides then taking, developing, printing, titling and assembling motion pictures of the Reclamation Service work. He was then also installing, wiring up and operating stereopticons and motion picture projection machines to accompany lecturers. That year he lectured on color photography at George Washington University and before the American Chemical Society.

In the winter of 1908–9 he was stage manager and photographer for Burr McIntosh who gave lectures on "Our Country," "Our Navy," "Our Island Possessions," etc., in the major cities of eastern United States. In the spring of 1909 he began photographic investigation in cinematography for Thomas A. Edison.

In 1910 he became Chief Photographer for the Thanhouser Film Co. and in 1911–12 built for Thanhouser the California Studio which was later used by Majestic, Reliance and Chaplin film companies. In 1912 he was chief photographer and often director of a large number of scenic, educational, dramatic and propaganda films. In 1913 he was in charge of the entire production of the Princess Brand Films for Thanhouser, combining direction and photography of such films as *Break Upon the Waters*, *The Little Church Around the Corner*,

Her Right to Happiness, *The Tangled Cat*, *Friday the Thirteenth*, *Her Way*, *A Shotgun Cupid*, *The Grand Passion*, *The Strike*, *The Campaign Manageress*, *The Mystery of the Haunted Hotel*, *The Water Cure*, *A Deep Sea Liar*, *Little Brother*, and many others featuring such stars as William Russell, Florence LaBadie, James Cruze, Margaret Snow, Muriel Ostrich, Mignon Anderson and John Lehnberg.

He was the cameraman on the first serial, *Million Dollar Mystery*, starring Margaret Snow.

In the winter of 1914 he was Chief Photographer for the Williamson Submarine Expedition to the West Indies. On that expedition he made the first motion pictures ever taken beneath the surface of the ocean, something which was a large factor in his being made a Fellow of the Royal Photographic Society of Great Britain in 1915.

In the summer after returning from the West Indies he took a troop of actors on a western trip making dramatic and scenic pictures in the national parks under the permission and indorsement of the Secretary of the Interior. That fall he lectured at the Smithsonian Institution, Museum of Natural History at New York, the Philosophical Society at Philadelphia, and others.

In 1915 he was engaged in photographic research for Technicolor with Prof. E. J. Wall at Massachusetts Institute of Technology, then in the years 1916 and 1917 successively was Chief Photographer for Henry W. Savage Motion Picture Productions and Annette Kellerman Co., Fox Pictures. In 1918 he was in charge of instruction at the U.S. Signal Corps School of Cinematography where 800 men were trained for overseas photographic units. In 1919 he was lecturing on photoplay making at Columbia University. Over 200 reels of instructional film were produced by him in 1920–21 for the Graphic Instructor, subsidiary of United Publishing Co. which used the films for department store training.

During the next year he was doing photographic and research work for the Rodman Wanamaker Indian Foundation and producing such films as *The Vanishing American*, *Marshal Foch's Visit to America* and *Indian Customs*. In 1922–23 he was Managing Director of the Orient and India Picture Corp., producing films from his own scenarios in the South Seas, Japan, China, Malaya, Burma and India. In 1924–28 he was Dean of the New York Institute of Photography, during which he wrote one of his books on motion picture photography which is now reported on the rare book lists. In 1928 he was technical correspondent and in charge of professional equipment sales for Bell & Howell. From 1929 until 1936 he was occupied as consultant on photographic and cine processes and patents, serving such clients as Terrytoons, Fox, Pathescope, Metro, Paramount, Universal, Eastman Kodak, Raycol of London, Societe Francais Cinechromatique of Paris, and Siemens & Halske of Berlin, holders of patents on the lenticular film color process which the Kislyn Corp. has owned in this country. In 1936 he became Assistant in charge of Motion Picture, Photographic and Sound Record Surveys at the National Archives in Washington, D.C., where he remained until 1946.

He was a member of this Society and was also a member of the American Society of Cinematographers, the Edison Pioneers and the Oval Table Society. He was credited with building the first optical printer and he designed many machines such as a combined micro-colorimeter and densitometer, disk recording machine, a machine for cleaning dirty or oily film, for color processes as well as for cartoon animation on which he had patents. He had been a frequent contributor to this *Journal*, as well as to many other periodicals. He had for several years been editor of the department "Motion Picture Photography" in *Moving Picture World* and had also for years edited "Amateur Cinematography" in *Camera Magazine*.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were Published in the April *Journal*.

Fred Schmid

After 53 years of service with the C. P. Goerz American Optical Co., New York, President and General Manager Fred Schmid has resigned from active work and is now living in retirement at his home in Larchmont, N.Y.

It was on September 13, 1898, when Fred Schmid's destiny was tied up with the Goerz interests. On that day, Fred Schmid, a young instrument-maker, applied for a position with the Goerz Optical Works in Berlin-Friedenau, Germany. After a few hours' interview with C. P. Goerz, the founder of the Goerz enterprises, the latter offered to send him to America to open a branch factory there, in order to meet the ever increasing demand for Goerz photographic lenses in the U.S.A. In a spirit of adventure young Schmid accepted the offer readily and, after six months of intensive study of the manufacturing methods of the parent house, he arrived in New York in May 1899 to set up shop. Since then the making of Goerz American photo-lenses was carried on here under his personal supervision.

The *American* firm was incorporated in 1906 as the C. P. Goerz American Optical Company and its assets and manufacturing rights were acquired through purchase by a small group of American citizens in 1920. The *German* Goerz Company was merged in 1926 with the well-known Zeiss Ikon Corp. in Germany. Today the *American* Goerz firm is the only company which supplies a full line of the Goerz Photo-lenses.

Fred Schmid, at first in charge of production, was made General Manager in 1910, Vice-President of the American company in 1920 and finally President in 1937. He made the last of his frequent business trips back to Germany during the summer of 1949. The company has announced that Mr. Schmid will continue to serve on its Board of Directors and in a consulting capacity.

Fred Schmid was born at Lehe, near Bremerhaven, on August 5, 1870, and next month will celebrate his 81st birthday with his three daughters at their summer cottage in South Salem, N.Y. He has been a member of this Society since 1929.

BOOK REVIEWS

Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses

By John F. Rider and Seymour D. Uslan. Published (1950) by John F. Rider Publisher, Inc., 480 Canal St., New York 13. 992 pp. + 8 pp. index + 3000 diagrams and illustrations. $8^1/_2 \times 11$ in. Price $9.00.

This valuable new book is a rather complete collection of practical information relating to modern oscillographs and their uses. There is the absolute minimum of mathematics included, and the authors have not resorted to too intense theoretical treatment. Only the essentials have been covered. Since the book is on a practical level it will undoubtedly find widespread acceptance.

The reader will find a description of practically every type of commercial oscillographic equipment included, together with information which the engineer can put to practical use every day.

As a matter of fact, there are 331 pp. devoted exclusively to instruments and accessory equipment. This rather complete coverage, in itself, will make the book extremely useful.

Cathode-ray tubes are fully covered in some 171 pp. Over 200 pp. are devoted to specific applications of oscillographs, and 107 pp. to circuit diagrams and various operating specifications. There is a complete bibliography at the conclusion of each chapter which will prove very valuable to the engineer for reference purposes.

The 1580 illustrations showing photographic reproductions of various waveforms will unquestionably prove very valuable to the average engineer, and the reviewer finds the collection one of the most comprehensive to be found anywhere in the literature.

It is regrettable that the word oscillograph has not been used instead of the term oscilloscope. The former is the more erudite term of the two and is undoubtedly to be preferred in scientific literature. Surely, the term oscillograph was the first word applied to the particular instrument, and an investigation of early writers on the subject will disclose its preference over all other terms. It was used, for instance, by J. B. Johnson in 1922 in the *Journal of the Optical Society of America* to describe "A Low Voltage Cathode-Ray Oscillograph," the first known practical instrument of this kind. A great many early references to the oscillograph are given in *The Cathode-Ray Oscillograph in Radio Research*, published by His Majesty's Stationery Office in London in 1933, and there is no reference to the word oscilloscope. This latter term has been widely used in the radio service field, but has not found great favor among engineers who are daily engaged in the study or design and development of cathode-ray oscillographs. This misuse of a word does not detract from the excellence of the material covered.

In summarizing, the reviewer has found this book to be an exceptionally fine reference work on the subject of cathode-ray oscillographs and their uses, and does not hesitate to recommend it as a valuable addition to engineering libraries everywhere.—*Scott Helt*, Research Div., Allen B. Du Mont Laboratories, Inc., 2 Main Ave., Passaic, N.J.

Progress in Photography—1940–1950

Editor-in-Chief, D. A. Spencer. Editorial Board, W. F. Berg, J. Eggert, L. E. Varden and T. A. Vassy. Published (1951) by The Focal Press, Ltd. Distributed by L. E. Varden, Pavelle Color, Inc., 533 W. 57 St., New York 19. 450 pp. + 10 pp. appendix. 150 illus. $7 \times 9\frac{1}{2}$ in. Price $10.00.

In 81 reports, 68 authors have recorded the progress of a decade in this volume. Some of their names are quite familiar to *Journal* readers. The opening article is by Glenn Matthews; E. W. Kellogg reports on sound recording; John Crabtree on processing; John Bradley on film storage.

The broad base of photography is covered by this book, with little detail given on any single phase; however, liberal reference lists are appended to each chapter.

Equipment progress is reported in terms of amateur equipment. There are some references to professional equipment. The new high-acetyl cellulose acetate film base gets one short chapter. Articles or chapters which include primarily motion picture subjects are: High-Speed Photography; Sound Recording for Motion Pictures; Recording with Galvanometer Oscillographs; Cine Radiography; Visual Aids for Instruction; Time and Motion Study; Job Training; Propaganda, Selling Aids and Demonstration Films; and a description of the functions and activities of the SMPTE.

It should not be assumed, however, that these reports have interest for only the motion picture engineer. Considering the broad base of our membership we counted 53 articles out of the 68 which have direct information bearing on some phases of our work.

Perhaps it is too much to ask, with so many subjects crowded into less than 500 pages, that a less selective annotation of equipment be employed! As we read some subjects we find, or sense, a partiality toward certain manufacturers. Important developments of competitors were not always reported. The editor might have condensed the three references or descriptions of the Polaroid Land camera to a single entry and added a few other interesting developments in the inches he gained.

The comment above, incidentally, applies to non-U.S. contributors as well as to

our compatriots. (About a third of the authors are American.)

Progress in Photography—1940–1950 should be a handy reference book with its international basis, especially when supplemented by the more detailed progress reports which appear in our *Journal.* It provides quick information on progress in England and Europe as well as our own, and the generous references will be of definite aid to the researcher. Its shortcomings are outweighed by the more positive aspects of the book, and readers may well find it a useful tool. The illustrative material is scanty but perhaps adequate.—*Don Bennett*, Associate Editor, Photo Dealer Magazine, 251 Fourth Ave., New York 10.

The Illumination of Photographic Darkrooms and the Determination of the Spectral Sensitivity of Photographic Material

By G. Weber. Translated from Danish into English by Vibeke Bonde. Published (1950) by the Academy of Technical Sciences and the Institution of Danish Civil Engineers on commission by G. E. C. Gad, 32 Vimmelskaftet, Kobenhavn K., Denmark. 280 pp. including appendix, bibliography and 12 pp. index. 166 illus. $6\frac{3}{4} \times 9\frac{3}{4}$ in. Paper cover. Price Danish Kr. 16,50 (about $2.00).

G. Weber, Professor of Illuminating Engineering at the Technical University of Denmark and President of the Danish Illuminating Engineering Society, has investigated the theory applicable to a judgment of what is the maximum light tolerable to photographic materials and the minimum light needed for adequate working conditions.

The author brings out the fact that darkroom illuminating should be chosen with regard to both the spectral sensitivity of the photographic materials to be handled and the sensitivity of the eye and that both of these sensitivities should be determined at the low intensities commonly used. In most cases this will require a source and filter combination.

The author states "...that the filters should have maximum efficiency, i.e., their absorption must be such as to cause minimum reduction of the light in relation to the eye and maximum reduction in relation to the plate." Theoretical consideration and calculations are discussed at considerable length and illustrative examples presented in unusually great detail. Some, but much less, attention is paid to practical trial methods. Under the heading "Direct Determination of the Permissible Illumination," there is recognition of the fact that in general the individual theoretical factors will not be precisely known. The statement, "None of these seven factors are known with any great certainty," is given as one reason for use of an experimental method. Again it is stated of the theoretical method presented, "But even if all these quantities were known, the method is of course far too complicated for practical purposes, although it may be of a certain theoretical interest."

This reviewer concurs in Dr. Weber's judgment; judged by this criterion, there are many, many pages "of a certain theoretical interest" and relatively few pages devoted to procedures intended for "practical purposes."—*D. R. White*, Research Laboratory Director, Photo Products Dept., E. I. du Pont de Nemours & Co., Inc., Parlin, N.J.

Audio Anthology

Compiled from *Audio Engineering*, C. G. McProud, Editor. Published (1950) by Radio Magazines, 342 Madison Ave., New York 17. 124 pp. incl. 210 illus. $8\frac{7}{8} \times 9\frac{3}{4}$ in. Price $2.00.

This compilation of 38 articles from *Audio Engineering* covers the period from May 1947 to December 1949. The selection of material has been largely directed toward the audio hobbyist. Eleven of the articles are on audio amplifiers. The remainder are on the subjects of loudspeakers, dividing networks, equalizers, noise suppressors, volume expanders and radio receivers.

Since the compilation is directed toward the audio hobbyist, the accent is on practical construction rather than on theoretical design considerations. However, when design information is necessary for the purpose of the article, it is presented in an understandable and usable form, as for

example in the articles on loudspeaker enclosures, dividing networks and multiple-speaker matching. The amplifiers described cover the range from phonograph preamplifiers to 30-watt power amplifiers. A considerable amount of space (10 articles) is devoted to the subject of frequency equalization, giving it a thorough coverage from a practical standpoint.—*G. W. Read*, Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.

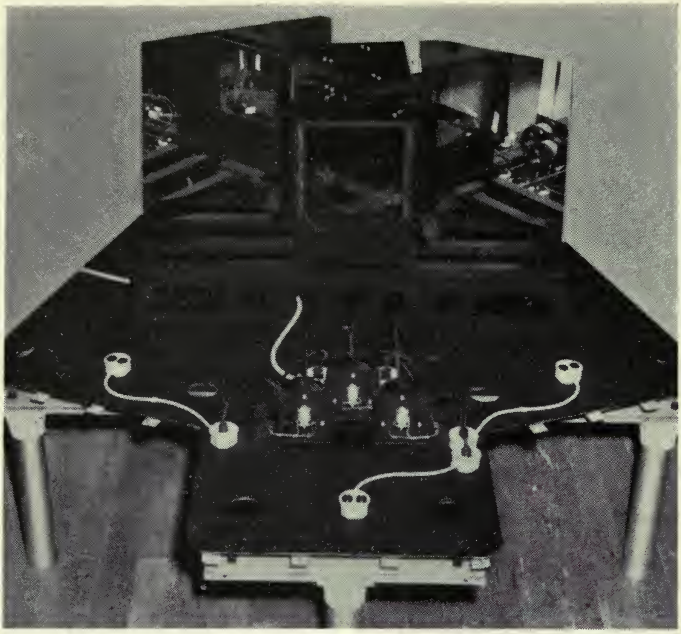
Bibliography on Stereography

Four hundred references have been published in mimeo form by the Stereo Society of America, covering magazines and journals from this country and from abroad. The references have a wide range—from editorials and popular articles to learned treatises. Copies of the Bibliography are available at $1.50 each from The Stereo Society of America, Inc., Owen K. Taylor, Secretary, 40 Monroe St., New York 2.

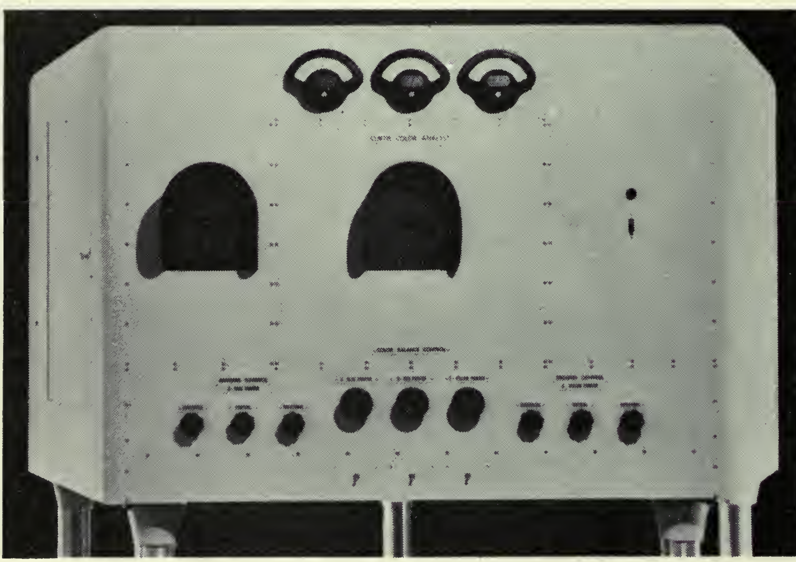
New Products

Further information about these items can be obtained from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.

Trade-marked the "Color-Tru Optical Bench," this equipment has been designed to enable the operator to judge intelligently the quality of photographic objectives and lens systems for most aberrations. Results are read directly by dial indicator in thousandths of an inch for comparisons between lenses. Attachments are available for holding cameras in alignment, nodal slide, lens boards and lens barrels. Targets are those of the U.S. Bureau of Standards. Checks can be made of resolution, color, focus, diaphragm location, effective aperture, cell separation, spherical aberration, element alignment and distortion. Prices range from $237.50 to $650.00, depending on accessories and on choice of microscope. The Color-Tru Optical Bench is available from Grover Photo Products, 2753 El Roble Dr., Los Angeles 41.



Curtis Color Analyst



Curtis Color Analyst

Color separation images may be evaluated, and any necessary corrections determined, with the **Curtis Color Analyst,** an instrument developed and manufactured by Curtis Laboratories, Inc., 2718 Griffith Park Blvd., Los Angeles 27, Calif.

The Color Analyst contains an optical system incorporating a beam splitter that enables the operator to see a fused image in color of three positive black-and-white separation images placed into the instrument, and illuminated by appropriately filtered light. Positive transparencies are required for the 11 × 14 in. Color Analyst or smaller models; black-and-white prints are needed for the large models. The intensity of any of the three illuminants may be varied to adjust the color balance of the image until it appears normal to the operator. The extents of such variations are indicated by means of dials or meters calibrated in terms of exposure variations required to obtain balanced color reproduction from any given set of separations. The light sources and filters may be chosen to match most nearly the characteristics of the inks, pigments or dyes of the final color reproduction process.

A 20 × 24 in. model of the Color Analyst has been built for the *Milwaukee Journal* where it is used to check color separation prints and black-and-white ink proofs.

Erratum

"Progress Committee Report," *Jour. SMPTE*, vol. 56, p. 568, May 1951.
Page 570, in title of Fig. 1 and in column 2, line 18: read *Camerette* for *Cameflex*. (This 16-/35-mm camera is known as the Cameflex in Europe but in the United States is the Camerette, according to new information from the Benjamin Berg Agency, 1213 North Highland Ave., Hollywood 38, Calif.)

Meetings of Other Societies

Biological Photographic Association, 21st Annual Meeting, Sept. 12–14, Kenmore Hotel, Boston, Mass.

Theatre Equipment and Supply Manufacturers' Association (in conjunction with Theatre Equipment Dealers), Oct. 11–13, Ambassador Hotel, Los Angeles, Calif.

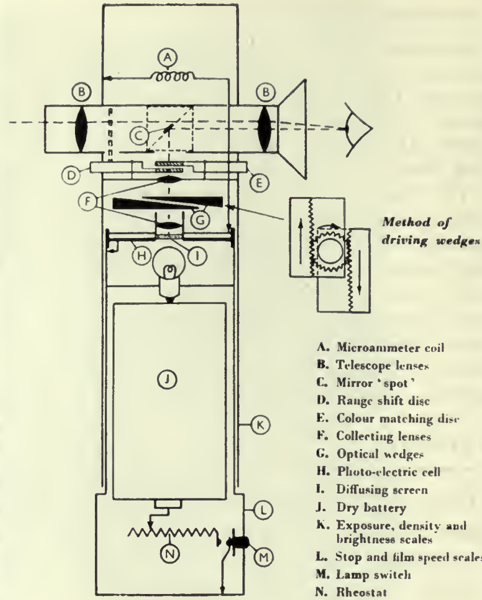
National Electronics Conference, Seventh Annual Conference, Oct. 22–24, Edgewater Beach Hotel, Chicago. The conference is sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers, Illinois Institute of Technology, Northwestern University and the University of Illinois, with participation by the University of Wisconsin and the Society of Motion Picture and Television Engineers.

The American Institute of Physics is holding a twentieth anniversary meeting in Chicago on October 23–27. Its member societies will hold meetings at that time as follows:

- Acoustical Society of America, Oct. 23–25
- Optical Society of America, Oct. 23–25
- Society of Rheology, Oct. 24–26
- American Physical Society, Oct. 25–27
- American Association of Physics Teachers, Oct. 25–27

UFPA Fifth Annual Workshop

On August 13–18 the University Film Producers Association held its fifth annual workshop on the campus of Indiana University. There was a formal program of panels on production problems such as scripting, sound techniques, films for television, distribution and animation as they affect the university film producer. Screenings of university productions were held at night. Housing was provided in one of the University dormitories. Arrangements were under the direction of Harold Otwell, Audio Visual Center, Indiana University, Bloomington, Ind.



The Visual Photometer is a pocket-size visual-comparison photometer, with a brightness range of 1,000,000 to 1 and its own internal comparison source, made in England by Salford Electrical Instruments, Ltd. Zoomar Corp., 381 Fourth Ave., New York 16, is the distributor in the United States. The motion picture industry finds application for the SEI instrument in the production studio or on location for determining correct exposure and screen brightness in projection. A photocell and microammeter together with a potentiometer in the comparison lamp circuit provide a reference brightness adjustment independent of the brightness or color sensitivity of the observer's eye. Aging of the dry cell is thus compensated for.

A pair of neutral density wedges gives the instrument a basic brightness range of 100 to 1 and additional filters shift the range up or down by factors of 100 giving extended foot-Lambert range of from 0.01 to 10,000. Two filters, one blue and one yellow, change the apparent color of the comparison spot to match the incident light color when reading brightness of an object illuminated in the first case by the sun, high-intensity carbon arc or "daylight" lamps, or in the second case by tungsten lamps or the "low-intensity" type of arc lamp.

In use the comparison spot appears superimposed upon the object whose brightness is being measured. The wedges are then moved slowly until the spot blends into the background. By appropriate choice of scales it is then possible to determine either brightness of the object in foot-Lamberts, or photographic exposure required. Since the spot subtends an angle of one-half degree, readings of small areas at inaccessible places such as drive-in theater screens, walls, ceilings and drapes that surround the screen in a motion picture theater and high parts of studio sets are "naturals" for the SEI instrument.

Back Issues of the Journal Available

Three and one-half years of the Journal, July 1947 through December 1950, are available at the job lot price of $25.00 from Mr. Max Prilik, c/o Circle Theater, 82 H Grant Circle, The Bronx 60, N.Y.

Foreword
Symposium on Screen Viewing Factors

By W. W. LOZIER, *Chairman, Screen Brightness Committee*

The subjective impressions received during the viewing of motion pictures are influenced by a great many factors. What the eye sees on the screen is the result not only of the conditions of the original scene, but also of the many steps of film processing and all the elements involved in the projection of the finished motion picture.

The Screen Brightness Committee has long been interested in the problem of establishing a scientific basis for determining preferred viewing conditions. The Committee sponsored a symposium on subjects pertaining to screen brightness at the Fall 1935 Convention of the Society. The record of this meeting, published in the May 1936 Journal, summarized the state of knowledge at that time and served as the basis of formulation of a recommendation for projection screen brightness for 35-mm motion pictures. Technological developments since that time have greatly changed some of the basic factors involved. A summary of work done and current thinking on the problem of screen brightness was contained in a discussion prepared by F. J. Kolb, Jr., and published in the April 1951 Journal. Subsequently, the Screen Brightness Committee sponsored the Screen Viewing Factors Symposium at the May 2nd session of the Spring Convention of the Society in New York this year. It is the conviction of the Screen Brightness Committee that the definition of the preferred conditions of viewing motion pictures is, in large measure, subject to scientific determination. The papers presented at the above-mentioned Symposium and published in the following pages are serious efforts and the first results of renewed activity in this direction.

E. M. Lowry, in his discussion of the luminance discrimination of the human eye, gives results of evaluation of the sensitivity of the eye, in this regard, as affected by the size and brightness level of the surrounding areas. MacAdam shows that the subjective impressions of hue and saturation are greatly influenced by the color quality of the surrounding light to which the eye is adapted. Critical levels of illumination, below which marked impairment of visual performance occurs, are indicated by Spragg in a study in a seemingly unrelated field which may, however, prove meaningful for motion picture viewing. Laboratory audience-preference studies by Guth relate preferred brightness levels of surrounding areas to the picture brightness. Logan, and Schlanger and Hoffberg present practical approaches to the prob-

lem of illumination of the areas surrounding the screen in a motion picture theater.

The "Report on Screen Brightness Committee Theater Survey" summarizes the results of measurement of screen brightness and related factors in 125 representative motion picture theaters in this country and in 18 West Coast review rooms used for viewing 35-mm motion pictures. The screen brightness for the majority of theaters is shown to be within or near the currently recommended standards, but there is a wide range of extreme values of brightness and other factors in a minority of the theaters which fall far outside the range of good projection practice.

It is the sincere hope of the Screen Brightness Committee that the papers reported in these pages will serve to stimulate many other worth-while technical studies on these subjects which will further assist in putting motion picture viewing on a scientific basis.

The Luminance Discrimination of the Human Eye

By E. M. LOWRY

Data are presented to show not only the effect of the luminance to which the eye is adapted on its ability to discriminate differences in luminance, but also the effect of the visual angle upon this important ocular function. That luminance discrimination depends upon whether the observer's attention is fixed upon a highlight or shadow region is shown by data on threshold luminance when scenes are being viewed in which the luminance varies over a wide range.

THAT THE VISUAL comfort of the audience in a motion picture theater has been of great interest for a long time is evidenced by the many papers on the subject of the projection screen and its surroundings, as well as by the activities of the Screen Brightness Committee of this Society. This interest arises in large part from the known fact that fatigue results when the eyes are used over extended periods in attempting to discern fine detail or to discriminate luminance differences when the luminance is so low that the visual system is working near its limit. As indicated by the title, this paper is concerned with the ability of the eye to discriminate differences in luminance. Its further purpose is to emphasize that, contrary to the often-accepted notion, the sensitivity of the human eye to luminance differences is much more affected by the luminance of the region immediately surrounding the point of attention than by the average luminance of the scene.

In the interest of clear understanding, some definition of terms is desirable. Throughout this paper, the word *luminance* is used in place of *brightness*.[1] The unit of luminance is the foot-Lambert[2] and is equal to the average luminance of a perfectly diffusing surface emitting or reflecting one lumen per square foot. That is to say, the average luminance in foot-Lamberts of any reflecting surface is the product of the illuminance in foot-candles by the reflectance of the surface.

Luminance discrimination or contrast sensitivity has been the subject of much investigation since the classical work of König and Brodhun some seventy years ago. A very large portion of the data collected has been under highly specialized conditions, such as a restricted field of view, low luminance surround, an

Communication No. 1412 from the Kodak Research Laboratories, a paper presented on May 2, 1951, at the Society's Convention, Screen Viewing Factors Symposium, at New York, by E. M. Lowry, Eastman Kodak Co., Kodak Park Works, Rochester 4. N.Y.

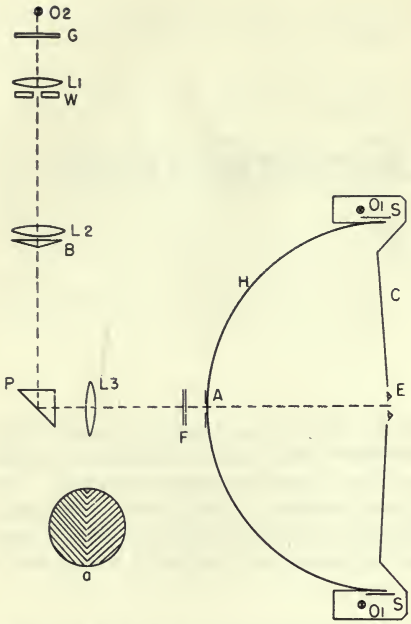


Fig. 1. Plan view of Visual Sensitometer.

artificial pupil, monocular viewing, etc. Such conditions have little, if any, resemblance to those which exist when an observer is viewing a scene; for example, a landscape out of doors. Normally he observes with both eyes, and the luminance may vary from nearly zero to thousands of foot-Lamberts. In addition, almost every scene presents to the eye a variegated pattern of color. Not only changes of light and shade exist, but also a gamut of many hues of varying saturation, as well as objects of manifold shapes and sizes. As an end result, the entire visual field is a complicated design made up of a host of variables, each of which may in some way affect the perceptions of the observer.

In an attempt to obtain numerical data under conditions simulating those of normal viewing, and yet provide adequate control of the factors of size of the visual field as well as of the test-spot luminance, and the luminance distribution in the surround, an instrument, which we have called a Visual Sensitometer, was constructed.

A plan view of this equipment is shown in Fig. 1. Here, H is a hemisphere one meter in diameter, with a conical-shaped cover, C. Both hemisphere and cover are painted inside with a matte white paint. At A is a test-field aperture of variable size and in the cover at E, a viewing aperture of sufficient diameter to permit placing the head of the subject in such a position that his visual field is almost 180°. The position of the observer's eyes with respect to the test aperture is fixed by means of a head and chin rest. Illumination of the sphere is accomplished by means of a ring of lamps, O_1, and the luminance of the sphere wall, that is, the surround or adapting field, is controlled by a ring-shaped shutter, S, which is adjustable over the gap between the rim of the sphere and the cover. With this arrangement, the luminance of the surround can be adjusted from zero to approximately 1000 ft-L.

Light from a biplane filament projection lamp, O_2, passes through the flashed opal glass, G, the lens, L_1, the neutral wedges, W, the lens, L_2, the biprism, B, the totally reflecting prism, P, the lens, L_3, the neutral filter, F, and the diaphragm, A, to the eyes of the observer at E. By means of this optical system, each eye of the observer views an aerial image of the biprism, B, in the form of a two-part field subtending an angle of 1.5° at the eye. The form of the field is shown in the insert at a. The luminance of the halves of this field is regulated by the neutral wedges at W, one of which can be adjusted by the person making observations.

In making a series of settings either for luminance match or for just-noticeable difference in luminance, the subject turns a knob which moves one of the wedges until he is satisfied that one field either matches or is just higher or lower in brightness than the other. An assistant records the wedge setting. While

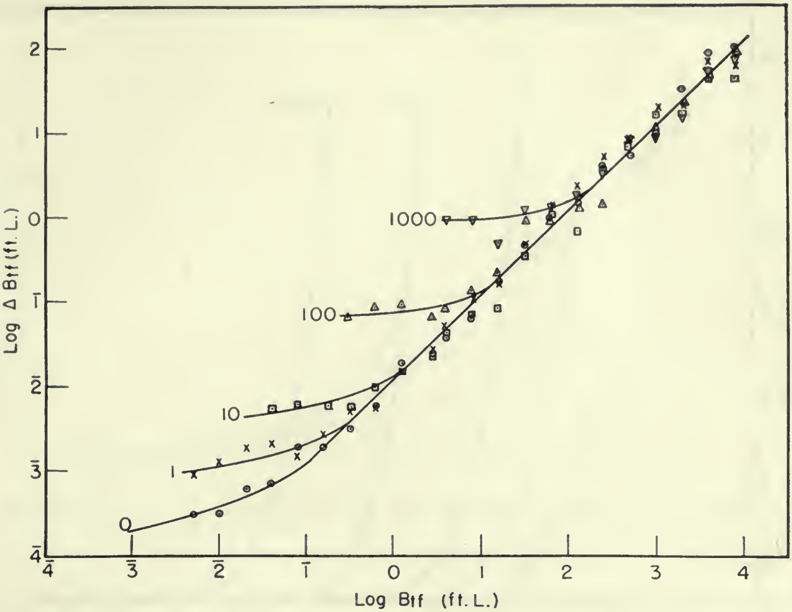


Fig. 2. Luminance discrimination, ΔB_{tf}, of the eye as a function of the test-field luminance, B_{tf}, in foot-Lamberts for surround luminances of 0, 1, 10, 100 and 1000 ft-L.

the method of just-noticeable difference was followed in the work reported in earlier papers,[3,4] a slight modification of that technique was adopted when securing the data presented here. Instead of setting for a just-perceptible difference between the two halves of the test field, the observer adjusted for equality of brightness and approached the balance point from each side. Five settings were made for each direction of approach to the balance point, and the average deviation from the mean was taken as a measure of the differential threshold, ΔB_{tf}. The symbol ΔB_{tf} is used to represent the difference in luminance between the two halves of the test field, which is just at the border line of discernibility. This method of securing the data seems to give the subject a little more confidence in reporting than when setting for least-perceptible difference, because it provides a somewhat more definite end point for his observations.

In Fig. 2 are shown the data obtained for a series of luminances of the conditioning field, and each point plotted represents the average of from three to five runs on different days for each surround luminance. Probably the most noticeable feature of these curves is that above a certain luminance of the test field the discrimination remains constant, regardless of the surround, and that the slope of the curve is very nearly 45°. This, of course, means that the much-discussed Fechner Fraction is also constant above this value. There is absolutely no indication from the data that the ability of the human eye to discriminate difference in luminance decreases even for values of the test field as high as 8000 ft-L. These results are in substantial agreement with those previously reported by the author[3] and by Jones.[4] Data by Steinhardt,[5] and by Craik[6] also demonstrate that contrast sensitivity remains constant even at the

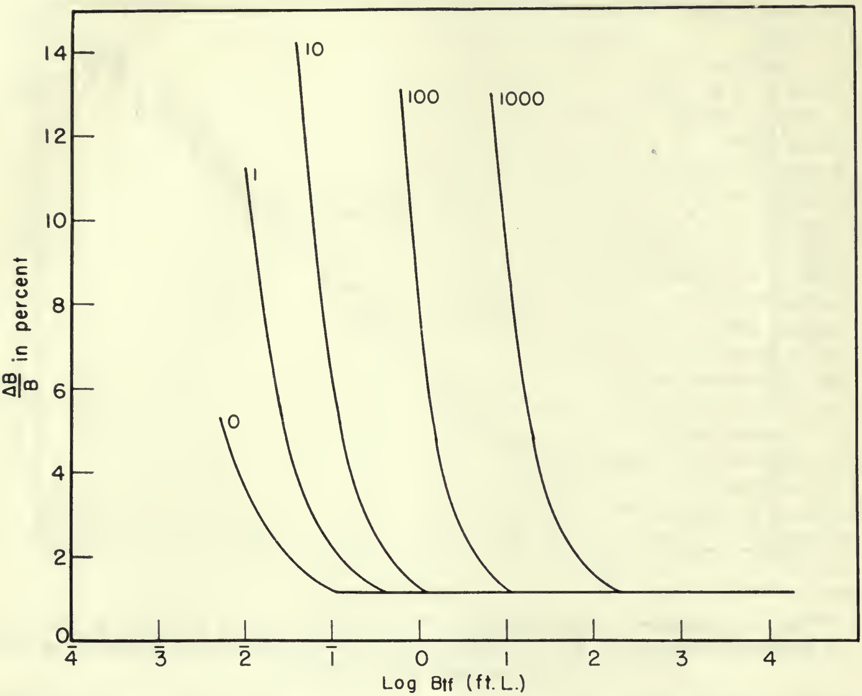


Fig. 3. Ratio of $\frac{\Delta B_{tf}}{B_{tf}}$, plotted as a function of log B_{tf} in foot-Lamberts for surround luminances of 0, 1, 10, 100 and 1000 ft-L.

highest values studied, which were approximately 10,000 and 4000 ft-L, respectively.

By means of a special optical system, an attempt was made to determine whether a sufficiently high luminance of the test field would reduce visual sensitivity for luminance differences. With this setup, a two-degree test field yielded a maximum luminance of approximately 32,000 ft-L, and, although rather persistent afterimages resulted, none of the observers participating in the test showed a decrease in his ability to detect a luminance difference of about 4%. In fact, each one reported that at the highest luminance the contrast was at least as apparent, if not more so, than at the lower ones. Although this test was more qualitative than quantitative, it seems safe to state that at luminances considerably above those encountered in any practical situation the visual mechanism retains its ability to distinguish a constant fractional difference in luminance.

The data shown in Fig. 2 have been replotted in Fig. 3 as the more familiar $\Delta B/B$ as a function of log B_{tf}. From the curves of this figure it will be seen that in the region of maximum luminance discrimination, represented by the flat portion of the curves, the ratio $\Delta B/B$ is just slightly over 1% and that this holds for test-field luminance above 0.3 ft-L for a dark surround. For higher values of surround luminance, namely, 1, 10, 100 and 1000 ft-L, the straight-line portion of the curves begins at correspondingly higher luminances of the test field.

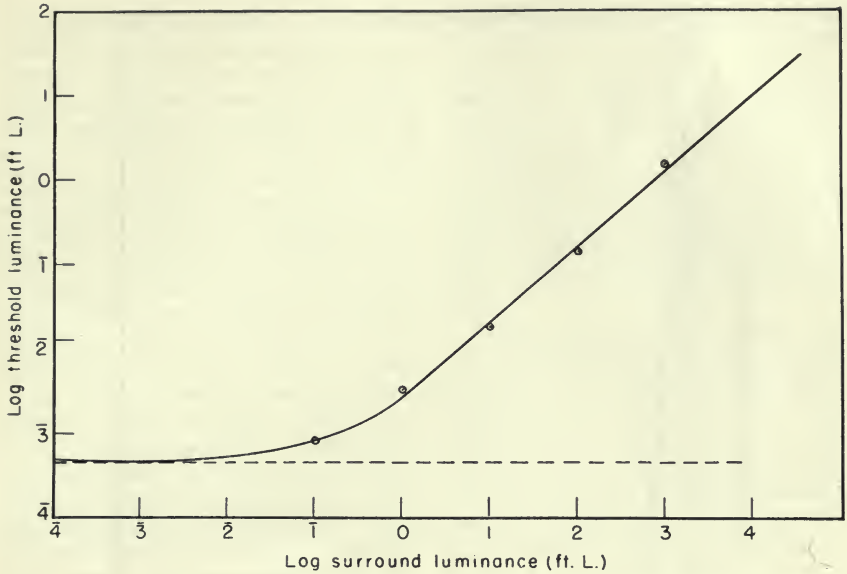


Fig. 4. Luminance of subjective black for surround luminances of 0, 1, 10, 100 and 1000 foot-L.

Subjective Black

Another aspect of the luminance discrimination of the eye which is of considerable importance is the luminance which will appear black. With the same equipment used in collecting data on contrast sensitivity, the visual threshold for luminance was determined with the same surround conditions as before, and the results are plotted in Fig. 4. As was the case with the differential threshold, so, with subjective black, the curve becomes linear above a surround luminance of approximately 1 ft-L, and has a slope of about 45 degrees. This means that for a surround higher than 1 ft-L, the luminance which will appear black is a constant fraction of that to which the eyes are adapted. As the conditioning luminance is reduced to zero, the values for subjective black approach the threshold for the dark-adapted eye, and the curve becomes asymptotic to the axis of abscissas.

Effect of the Size of the Surround on Threshold Luminance

While it is necessary to have information as to how the visual system responds to luminance and luminance differences, it is also important to know the effect of the size of the conditioning field on this function. For this purpose, a simple instrument called an "adaptometer" was built. It consisted of a brass tube 16 in. long and 1.5 in. in diameter, blackened both inside and out. In one end of the tube a small tungsten filament lamp was mounted behind a disk of flashed opal glass. In front of the opal glass was a black diaphragm with a 1-in. aperture which served both to limit the size of the field and to eliminate specular reflectance from the interior walls of the tube. By means of a long flexible wire cable, the lamp was connected to a 6-v storage battery through an ammeter, a rheostat, and a microswitch in the hands of the operator. The luminance of the opal

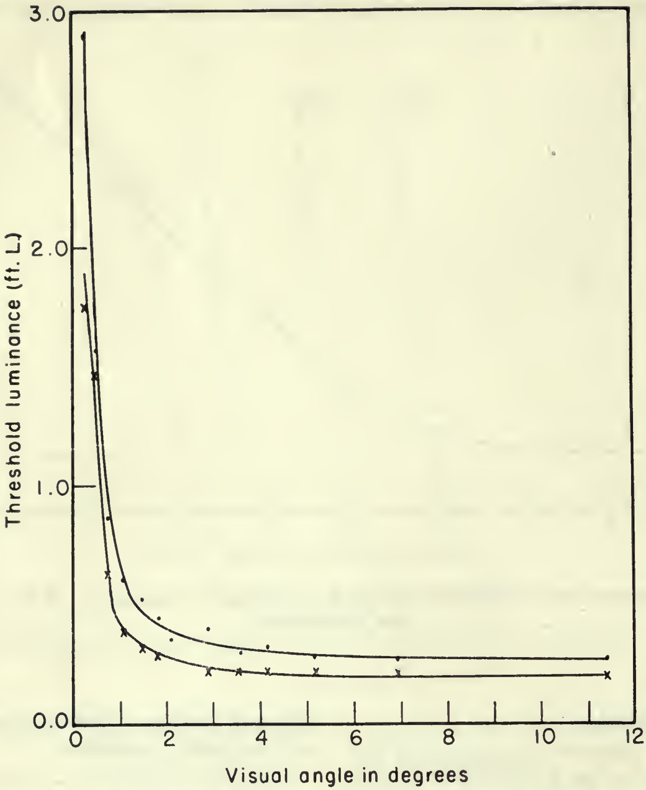


Fig. 5. Luminance of subjective black as a function of visual angle for constant surround luminance. ●—white target = 348 ft-L, gray rings 5.5 ft-L; x—white target = 211 ft-L, gray rings 3.2 ft-L.

glass in foot-Lamberts was measured for a series of filament currents, and a calibration curve of luminance as a function of current plotted.

For the purpose of making readings, the observer took up his station at a distance of 20 ft from the adaptometer. The instrument had previously been placed in line with the part of the scene to be investigated. Then, while viewing the opal glass, which at this distance subtended an angle of 15 min, through the open end of the blackened tube and against the background chosen, the observer adjusted the lamp current until by repeated interruptions of the current he could no longer distinguish a flashing of the light from the lamp. The luminance of the opal glass at the current for disappearance of the flashing light represented threshold luminance or subjective black. Of course, variation of the lamp current produced a change in the color of the light emitted, but, since the luminances were quite low, it was felt that this effect could be neglected. Furthermore, because of the small filament dimensions, there was little lag between current pulses and filament temperature on either making or breaking the circuit.

With this equipment set up behind a circular white target having a hole in the center to accommodate the end of the adaptometer tube, a series of threshold

determinations was made. The luminance of the target was maintained at a constant value, and a number of different-sized black rings were placed on the white background to present a variety of sizes of visual angle. The size of the white target was 12° at the eye, and the rings varied in size from 0.5 to 12°.

Measurements at two luminance levels (Fig. 5), namely, 348 ft-L and 211 ft-L, demonstrated that for visual angles over about 3° the effect on subjective black is negligible. In other words, it is the luminance of the object which lies close to the point of fixation that primarily controls visual sensitivity. This same effect has been reported by Wright[7] and by Crawford.[8] In studies of motion picture projection, Reeb[9] found that only the luminance of the center of the screen was of importance and that varying-sized areas of the picture had no effect on the ability of the eye to distinguish differences in screen luminance.

Threshold Luminance Under Field Conditions

So far, the results reported have been those obtained in the laboratory under controlled conditions. In order to test the visual response when viewing outdoor scenes, the adaptometer, mounted on a tripod, was carried to the location selected and set up so that it was viewed with the various points of interest in the scene as the immediate surround. For purposes of record and future experiments, a camera was placed at the observer's station and the scene photographed. Figures 6, 7 and 8 illustrate the instrument as used. The data printed on the figures show the luminance at the point indicated as well as the value obtained for subjective black. Up to the present, only a few scenes have been investigated, so that the data can be nothing more than indicative. They have been plotted in Fig. 9, together with the curve for the threshold taken from Fig. 4.

While at first sight there appears to be little correlation, and perhaps even some contradiction, between the values obtained in the laboratory and those resulting from observations in the field, a number of factors must be considered in drawing conclusions. It may be said, however, that the results do line up more or less in the order expected, that is, the lower the luminance of the area immediately surrounding the adaptometer, the lower will be the luminance of subjective black.

Visual phenomena as examined and reported by a large number of investigators have shown that what an observer perceives at any particular place in the visual field at a given time is dependent not only on the immediate stimulation, but also upon the preceding stimulation from the entire field and upon that from the region closely surrounding the test area. A part of the discrepancy, in the results reported here, is probably caused by the radical difference in the surrounds. In the laboratory, the adapting fields were uniform, while in actual scenes they were extremely nonuniform. Because of this lack of uniformity, the difference in completeness of adaptation for the particular area tested may well have been a contributing factor in the lack of agreement shown. It is very difficult to gaze steadily at a given point for two or three minutes until the eyes become thoroughly adapted to the luminance closely adjacent to the test field, and this is especially true when the surround consists of a complex pattern, such as is the case in the average outdoor scene. For the case of a uniform conditioning field, slight eye movements are not of great consequence, since the conditioning luminance remains constant. When a variable luminance is present, however, any slight shift in direction of view will result in a change of adaptation.

In the opinion of the writer, the chief value to be derived from the data taken in the field is their evidence as regards the difficulty of interpreting the results of

Fig. 6. Illustration of the use of the adaptometer for field work.

Fig. 7. Illustration of the use of the adaptometer for field work.

Fig. 8. Illustration of the use of the adaptometer for field work.

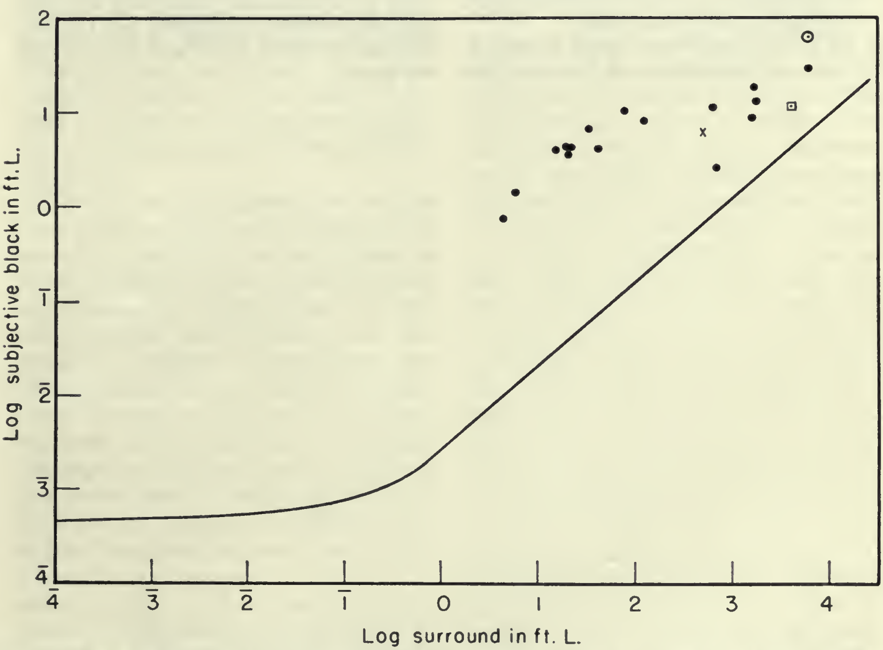


Fig. 9. Results obtained for subjective black when viewing outdoor scenes. Solid curve represents data taken in the laboratory.

x — from Fig. 6; ⊡ — from Fig. 7; ⊙ — from Fig. 8.

controlled experiments on visual function in terms of practical problems. Before this may be done satisfactorily, a great deal more information must be obtained on the actual viewing situation.

References

1. L. A. Jones, "Colorimetry: preliminary draft of a report on nomenclature and definitions," *J. Optical Soc. Am.*, vol. 27, pp. 207–213, June 1937.
2. *Illuminating Engineering Nomenclature and Photometric Standards*, Sec. 05.070, Illuminating Engineering Society, New York, 1942.
3. E. M. Lowry, "Some experiments with binocular and monocular vision," *J. Optical Soc. Am.*, vol. 18, pp. 29–40, Jan. 1929.
4. L. A. Jones, "Recent developments in the theory and practice of tone reproduction," *Phot. J.*, Sec. B, vol. 89B, pp. 126–151, Nov.-Dec. 1949.
5. J. Steinhardt, "Intensity discrimination in the human eye," *J. Gen. Physiol.*, vol. 20, pp. 185–209, Nov. 1936.
6. K. J. W. Craik, "The effect of adaptation on differential brightness discrimination," *J. Physiol. London*, vol. 92, pp. 406–421, May 1938.
7. W. D. Wright, *Researches on Normal and Defective Color Vision*, C. V. Mosby, St. Louis, Mo., 1947, pp. 230–231.
8. B. H. Crawford, "The effect of field size and pattern on the change of visual sensitivity with time," *Proc. Roy. Soc. London*, vol. 129B, pp. 94–106, June 1940.
9. O. Reeb, "A consideration of the screen brightness problem," *Jour. SMPE*, vol. 32, pp. 485–494, May 1939.

Discussion

Anon: Approximately how many subjects have you tested in each viewing situation?

E. M. Lowry: We've had, in all, five different subjects.

Anon: Did you get the impression that the results would have been much the same if you had used a great many more subjects?

Mr. Lowry: The curves might have been somewhat more smoothed out with a greater number of subjects, but I believe the results would have been substantially the same.

Influence of Color of Surround on Hue and Saturation

By DAVID L. MACADAM

Loci of constant hue are shown for daylight, tungsten light, and green and blue surrounds. Loci of constant saturation are shown for daylight and tungsten-light surrounds. The effects of field size and simultaneous contrast are also shown.

THE APPEARANCE of a projected color picture depends on the state of adaptation of the audience. This is governed by the picture itself, by its predecessors within the past few minutes, and, to an important extent, by the color of the light in the field of view surrounding the screen. This last factor is the subject of this paper.

The effects of adaptation to various surrounding colors are qualitatively well known. Usually the picture appears to be off balance, with a predominant hue approximately complementary to the color of the surroundings. For this reason, chromatic surroundings are frowned upon by some makers of color films. Furthermore, even a neutral surround, albeit rather low in intensity, stabilizes the adaptation of the audience and causes them to notice unintentional variations of balance in a film. In an almost completely darkened theater, the projected picture governs the adaptation of the audience so as to compensate, more or less completely, for accidental variations of balance. Any illumination of portions of the visual field near the screen provides a reference white, so that variations of balance become more noticeable. For this reason, some makers of color films strongly recommend that the light in the surroundings be kept to the bare minimum required for safety.

As other speakers in this symposium have indicated, considerably more than the statutory minimum is necessary for comfort and "good seeing." Therefore, it seems desirable to have some quantitative data concerning the effects of the color of the surround on the hues and saturations perceived in projected pictures. Such data may indicate the best colors for surrounding illumination, so as to obtain optimum safety, comfort and vision with minimum disturbance of the hues perceived in the picture. Adequate data may indicate some condition of balance which, paired with a particular quality of light in the surround, will cause the least perceptible effects for normally expected variations of balance and auditorium lighting.

Communication No. 1419 from the Kodak Research Laboratories, a paper presented on May 2, 1951, at the Society's Convention Screen Viewing Factors Symposium, at New York, by David L. MacAdam, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y.

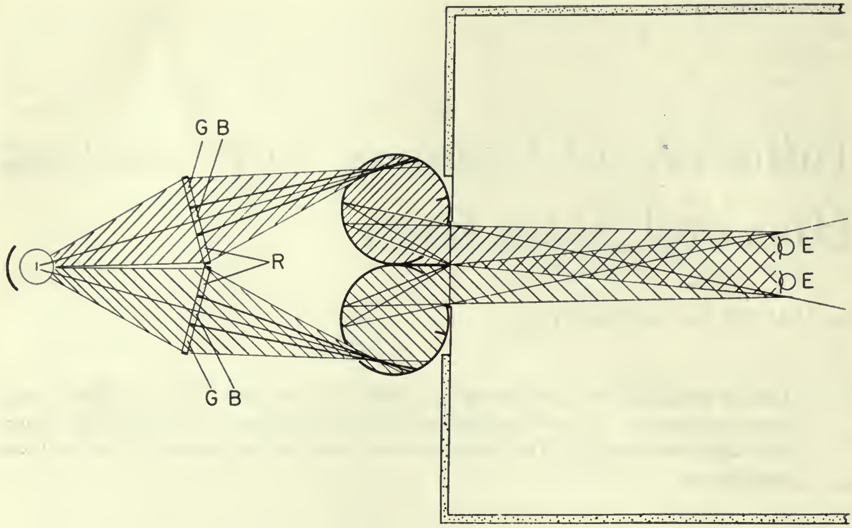


Fig. 1. Schematic diagram (horizontal cross section) of twin colorimeter, observing booth and observer's eyes.

To obtain and show such data, it is necessary to employ a method of measuring colors which is independent of variations of adaptation of the observer. With such a method, it is possible to determine the variations of measured colors which are required to produce equivalent effects under various conditions of adaptation.

A method, of the kind required for measuring colors and for representing the effects in which we are interested, was recommended in 1931 by the International Commission on Illumination. It was adopted by the American Standards Association as a War Emergency Standard in 1942, and within the last month has been reaffirmed as a regular American Standard.[1] The method has been described previously in this Journal.[2,3] The chromaticity diagram, which is commonly used to represent the results of color measurements, is very useful for representing and interpreting the results of quantitative research on color vision. Any color is always represented by a fixed point in the chromaticity diagram, regardless of the effects of adaptation in changing the perceptions arising from that color. This property of the chromaticity diagram implements the psychophysical definition of color[4] as "characteristics of light." These characteristics are independent of the state of adaptation of the observer. On the other hand, the chromatic attributes, hue and saturation, of the sensation resulting from any color, depend very much on the observer's state of adaptation. The coordinates of the point representing a color do not change, but hue and saturation do, when the color of the surround is changed.

The experimental arrangement used to get the desired data is indicated in Fig. 1. This is a horizontal cross section through a twin colorimeter, the observing room, and the observer's eyes.[5] The amounts of light passed by the red, green and blue filters, R, G, B, are varied by rectangular diaphragms, moved in vertical slots by remote control. These beams are mixed in the interiors of two hollow white spheres. The blended light within the spheres is viewed through portions of two plastic Fresnel lenses.

They appear as two adjacent semicircles. They are surrounded by a fluorescent cloth which glows with light of whatever color is desired. The cloth is irradiated with ultraviolet energy, which excites the surround but does not contaminate the colors of the light in the central field.

Figure 2 shows series of points in the chromaticity diagram. Each series represents colors of various saturations, all of which appear to have the same hue when seen with a black surround. The point W represents the color which appears to be white when no other colors are visible. The innermost point on each curve represents the color which appears to be white when the adjacent semicircle has the color represented by the outermost point. The differences between W and the innermost points, therefore, represent the effects of simultaneous contrast, and indicate possible effects of various colors in a picture on the appearance of neighboring colors in the picture.

Figure 3 shows series of colors which appear to have constant hue when surrounded by light matching the chromaticity of a blackbody at 3200 K. These curves are entirely different from the preceding ones. Their center of convergence represents a color that appears white when seen alone in such surroundings. The innermost point on each curve represents the color that appears white in such a surround, when seen side by side with the saturated color represented by the outermost point. Figure 4 shows the constant-hue series and the effects of simultaneous contrast in a blue surround, the color of which is indicated by the cross. Figure 5 shows constant-hue curves and the effects of simultaneous contrast when the general surround is green.

The preceding results were obtained with a test field subtending 12°. Figure 6 shows results obtained with a test field subtending 2°, with a surround only slightly greenish compared to daylight. In this case, hues particularly easy to remember were chosen. Thus, the yellow was neither greenish nor reddish, and the purple was not predominantly bluish nor reddish. The innermost extremity of each curve again represents the color which appeared white in one semicircle, when the saturated color represented by the outer extremity was in the adjacent semicircle.

The oval curve represents a series of colors of various hues but equal saturation, as judged by comparing neighboring hues in the 2° field.[6] These comparisons were begun at yellow and progressed through orange, red, purple, blue and green, back to yellow. The sequence was then reversed, with results which verified quite closely the results of the first sequence. The circle near the center represents the color of the surround, which at all times appeared as an acceptable white.

Figure 7 shows similar results for the same hues, and for constant saturation, with a surround nearly matching the color of a 3200 K blackbody light source. The results for the two different colors of surround are compared in Fig. 8. The saturations corresponding to the constant-saturation ovals were not necessarily equal in the two surrounds.

Very few data of the kind shown here have been published. Bouma and Kruithof[7] identified sets of colors which appeared to have the same hues in several surrounds. They did not determine constant-hue loci, estimate the saturations of their colors, or evaluate the effects of simultaneous contrast. As a matter of fact, they assumed the constant-hue loci to be straight lines radiating from the point representing the surround, and they drew far-reaching conclusions from extrapolations based on that assumption.

Newhall, Nickerson and Judd[8] published curves of constant hue and saturation derived from observations of Munsell paper samples in daylight. Helson and Grove[9] studied the changes of hue, lightness and saturation of surface colors

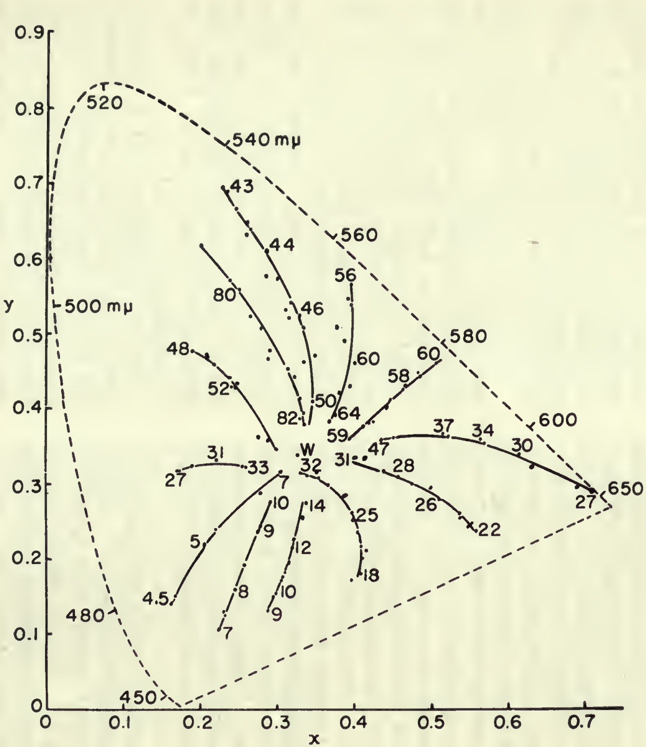


Fig. 2. Loci of constant hue in dark surround. Luminances (foot-Lamberts) necessary for constant brightness for each hue are shown by numbers printed near typical points. Different hues are not necessarily equally bright.

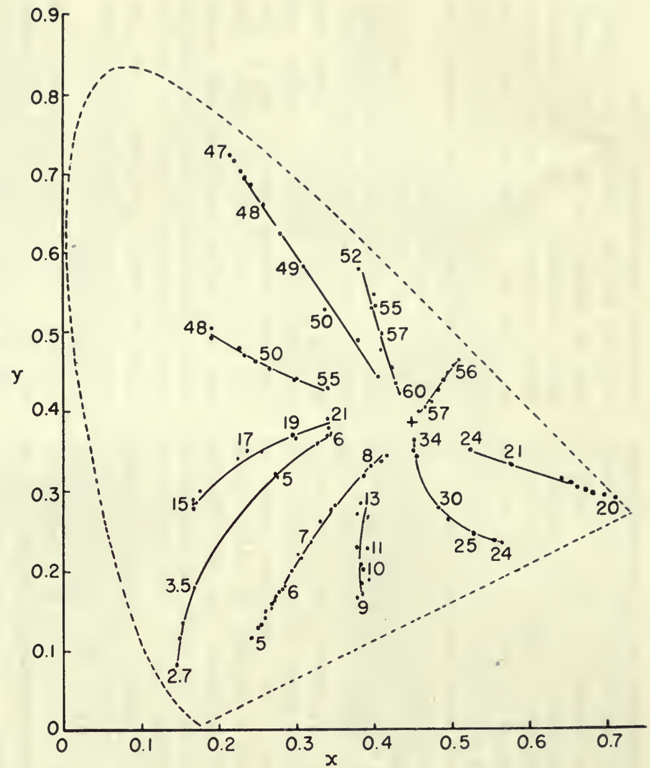


Fig. 3. Loci of constant hue for surround of approximately tungsten-light quality. Luminances for constant brightness are shown numerically.

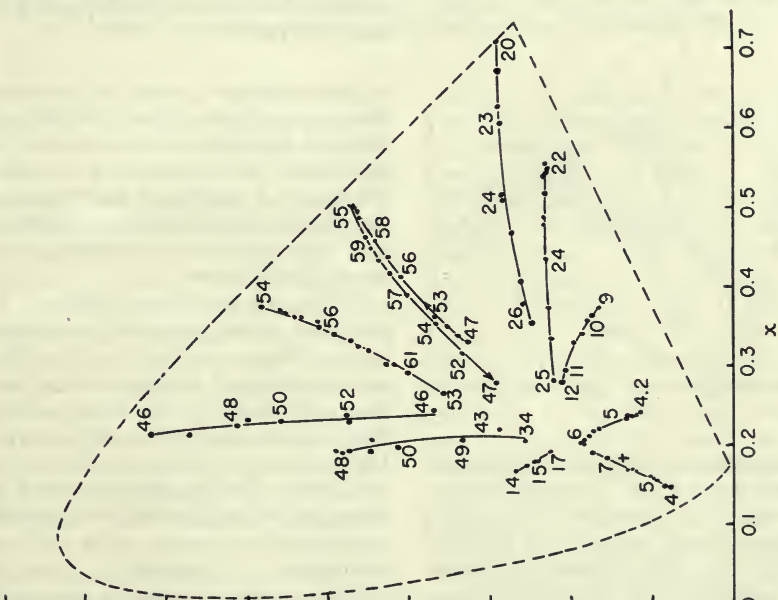


Fig. 4. Loci of constant hue for blue surround (shown by cross).

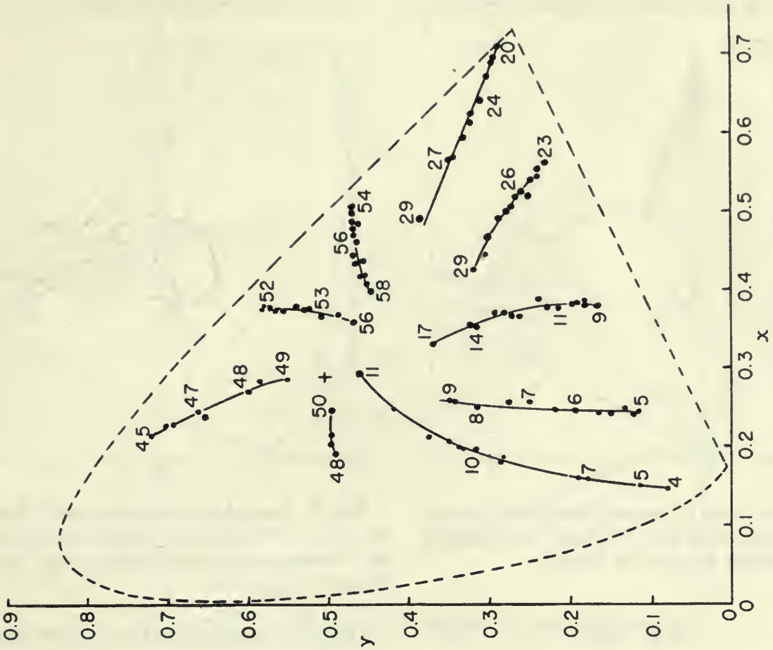


Fig. 5. Loci of constant hue for green surround (shown by cross).

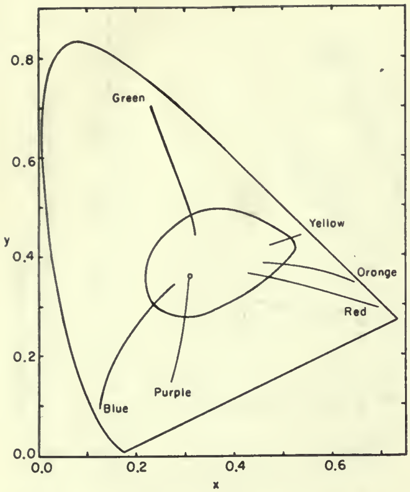


Fig. 6. Loci of named hues and of constant saturation in a 2° field, surrounded by daylight (shown by circle).

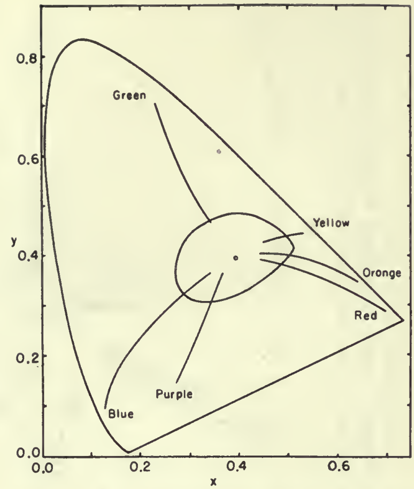


Fig. 7. Loci of named hues and of constant saturation in a 2° field, surrounded by incandescent-tungsten-quality light (shown by circle).

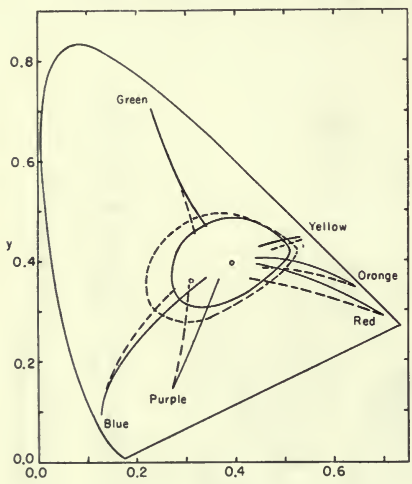


Fig. 8. Comparison of loci of same hues, and of constant but not necessarily equal saturations, in 2° field surrounded by daylight (broken-line curves) and tungsten light (solid-line curves).

in passing from daylight to incandescent-tungsten-lamp light. The meaning of their results is obscured by the fact that the color stimuli, adaptations and perceptions were all permitted to change simultaneously. To determine unambiguously the effects of adaptation on color sensation, it seems advisable either to keep the stimuli unchanged and report the hue and saturation resulting for different adaptations, or to readjust the stimulus for each adaptation so as to keep the hue and saturation unchanged, as was done by Hunt,[10] and as was done for hue, although not for saturation, in the present investigation.

Within the past year, Richter[11] has published curves purporting to represent various degrees of saturation. These were interpolated and extrapolated from the curve shown by the broken line in Fig. 9. The solid curve is that shown in Fig. 6, for adaptation to daylight. Unfortunately, Richter did not control the adaptation of his observer, nor determine what stimulus appeared white under his conditions of observation. Since his judgments of equal saturation were made with a dark surround, it might be presumed that white is represented by the

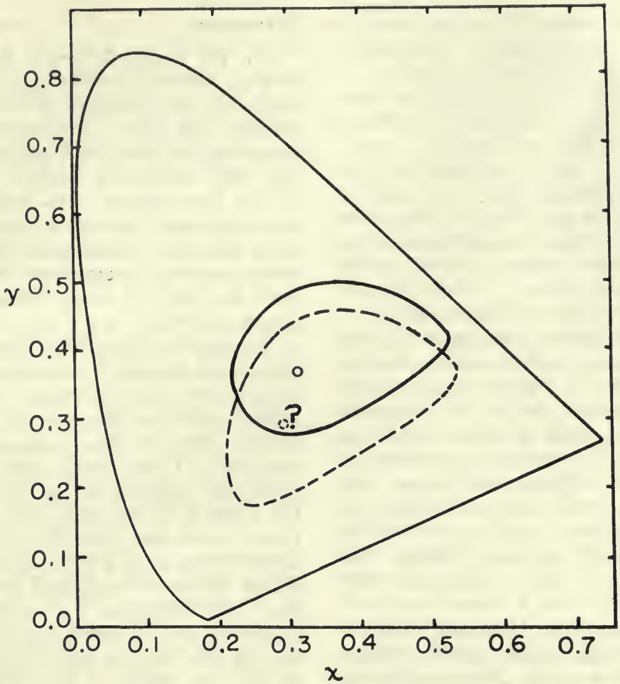


Fig. 9. Comparison of Richter's locus of constant saturation in dark surround with locus of constant saturation in daylight surround (solid-line curve).

point marked with a question mark. This guess is based on determinations of white in dark surrounds by Priest,[12] Helson and Michels,[13] Hurvich and Jameson,[14] and MacAdam.[5] However, the effects of simultaneous contrast, indicated by Fig. 2, must have resulted in a different criterion of white and a different basis for saturation for each hue. The interpolation of curves for other degrees of saturation in Richter's method was based on the implicit assumptions that white paper would appear white when seen through the instrument used to determine the curve in Fig. 9, and that the effects of simultaneous contrast would not disturb the criterion for white. Since he did not use any surround to control adaptation, these assumptions do not seem to be admissible. Therefore, the curves Richter interpolated and extrapolated are of doubtful significance.

In conclusion, it can be stated that the color of the surround influences, to an important extent, the hues and saturations perceived in a picture. The results shown in Figs. 2 to 8 are intended as a guide in estimating the kind and degree of effects to be expected with various surrounds. These results also indicate that engineers can no longer be content with looking at colors. The effects of adaptation are too great to be ignored, and are too complicated for guesswork, or for reasoning based on casual impressions. In order to deal effectively with color, it is necessary to measure color.

References

1. American Standards Association, "Method of spectral photometric measurement of color," Z58.7.1, and "Method of determination of color specifications," Z58.7.2, 1951.

2. D. L. MacAdam, "The fundamentals of color measurement," *Jour. SMPE,* vol. 31, pp. 343–348, Oct. 1938.
3. D. L. MacAdam, "Quality of color reproduction," *Jour. SMPTE,* vol. 56, pp. 487–512, May 1951.
4. Committee on Colorimetry, "The psychophysics of color," *J. Opt. Soc. Am.*, vol. 34, pp. 245–266, May 1944.
5. D. L. MacAdam, "Loci of constant hue and brightness determined with various surrounding colors," *J. Opt. Soc. Am.*, vol. 40, pp. 589–595, Sept. 1950.
6. D. L. MacAdam, "Influence of visual adaptation on loci of constant hue and saturation," *J. Opt. Soc. Am.*, in press.
7. P. J. Bouma and A. A. Kruithof, "Hue-estimation of surface colours as influenced by the colours of the surroundings," *Physica*, vol. 9, pp. 957–966, Dec. 1942; *ibid.*, vol. 10, pp. 36–46, Jan.–Feb. 1943; "Chromatic adaptation of the eye," *Philips Tech. Rev.*, vol. 9, no. 9, pp. 257–266, 1947/1948.
8. S. M. Newhall, D. Nickerson and D. B. Judd, "Final report of the Optical Society of American Subcommittee on the Spacing of Munsell Colors," *J. Opt. Soc. Am.*, vol. 33, pp. 385–418, July 1943.
9. H. Helson and J. Grove, "Changes in hue, lightness, and saturation of surface colors in passing from daylight to incandescent-lamp light," *J. Opt. Soc. Am.*, vol. 37, pp. 387–395, May 1947.
10. R. W. G. Hunt, "The effects of daylight and tungsten light adaptation on color perception," *J. Opt. Soc. Am.*, vol. 40, pp. 362–371, June 1950.
11. M. Richter, "Untersuchungen zur Aufstellung eines empfindungsgemäss gleichobständigen Farbsystems," *Z. wiss. Phot.*, vol. 45, pp. 139–162, 1950.
12. I. G. Priest, "The spectral distribution of energy required to evoke the gray sensation," *Sci. Papers, Bur. Standards* vol. 17, pp. 231–265, 1921.
13. H. Helson and W. C. Michels, "Effect of chromatic adaptation on achromaticity," *J. Opt. Soc. Am.*, vol. 38, pp. 1025–1032, Dec. 1948.
14. L. M. Hurvich and D. Jameson, "A psychophysical study of white," *J. Opt. Soc. Am.*, vol. 41, pp. 521–536, Aug. 1951.

Discussion

W. W. Lozier: I would like to have you go through briefly again what you did in the manipulation of those two parts of the test field. I missed something important in there and perhaps someone else did, because it seemed to me that if you had control over both halves of the field, and you were trying to make some sort of a photometric balance, you would come to a condition where they'd both be just the same. Now what did I miss in there?

D. L. MacAdam: The observer never was asked to match a color completely. He was, for instance, asked to establish a yellow, which in his opinion was neither reddish nor greenish, in the right half of the field. Then, during the rest of that particular experiment, he did not touch the controls of the right half of the field. He adjusted the controls of the left half of the field in such a manner that he maintained the same brightness and the same hue, but decreased the saturation. He continued this by small steps of desaturation all the way to white. He made 20 or 30 such steps. It is easiest and customary to progress from the saturated hue to white in regular sequence. Each time, he desaturated the yellow a little more and kept the brightness constant, but the thing to which we asked the observer to pay most attention was to keep the same hue, neither too orange nor too green. Therefore, each time we recorded a set of data the field was not matched completely, but was matched according to only two of the three attributes of color. It was matched in hue and matched in brightness, but not in saturation.

We did similarly for the saturation loci. In that case we asked the observer to change the hue. There was another difference from the constant hue experiment. In that, we kept the right-hand side of the field at its maximum possible saturation throughout the whole series. But in the equal saturation experiment, the observer changed the hues of both halves of the field in turn. First, he adjusted to obtain a moderate saturation of yellow in the right-hand side of the field, then the observer adjusted the controls of the left side to obtain an orange equal to the yellow in saturation and brightness.

But, of course, it was a different hue. Then he left that side of the field alone and returned to the right-hand side of the field which he adjusted to an even redder orange, equal to the other half of the field in two attributes, saturation and brightness. But the third attribute, hue, was different.

Dr. Lozier: Thank you, that helps a lot.

M. W. Baldwin, Jr.: I have two questions. First, were your observers experienced or naive?

Dr. MacAdam: They were experienced in the use of this apparatus. We're very naive in subjective judgement. If we say that two colors appear to be equally saturated, no training has contributed to that judgement.

Mr. Baldwin: My second question is, how did you convey to them what you meant by the word hue?

Dr. MacAdam: We did not attempt to teach the observer what hue means. The purpose of the experiment is to determine what the *observer* means by hue. As a matter of fact, we did not use the word hue when telling the observer what to do. We asked him to choose a yellow, for instance, that he felt sure he could remember, one in which neither red nor green was noticeable.

Mr. Baldwin: Would you have been successful with this if you had called in a mail girl as an observer?

Dr. MacAdam: If we had called in a mail boy, he might not have been sufficiently interested in color. I think a mail girl would have served very well.

Anon: Are there data now available in respect to the direct viewing of transparencies? Could your data be applied to the direct viewing of color transparencies?

Dr. MacAdam: My impression is that it could be applied in a general way, that is, one could estimate rather closely the extent of the effect, of which we have been aware for a long time, that a colored surround influences the apparent balance of a picture. I think we could now say how much the balance is influenced and how much one would have to adjust the balance in order to compensate for the effect of the surround. As for the mutual color adaptation effects of details within the picture itself, I don't believe we have enough data.

Anon: Thank you. The reason for the question is that there is now a Subcommittee of ASA charged with the responsibility of developing, possibly, an American Standard for the direct viewing of transparencies.

Visual Performance on Perceptual Tasks at Low Photopic Brightnesses*

By S. D. S. SPRAGG

Subjects, rigorously screened for visual abilities, were tested on a variety of visual perceptual tasks. A brightness range of 0.005 to 6.0 ft-L (at the subject's eye) was used. For each task a critical brightness level (approximately 0.02 to 0.05 ft-L) was found, below which visual performance was impaired (as measured by speed and accuracy scores), and above which increases in brightness produced little or no improvement in visual performance. Implications are discussed.

THE EXPERIMENTS described are part of a research project concerned with human visual performance as it is related to problems of airplane cockpit and instrument illumination. More specifically, study has been made of the minimum brightness levels needed for the effective performance of visual perceptual tasks. Toward this end, experiments have been carried out on the speed and accuracy with which subjects can read photographic reproductions of instrument dials as a function of the intensity of illumination provided. Studies have also been made on the adequacy of visual performance on such perceptual tasks as: judgments of magnitude of a common illusion, thresholds for perception of motion, accuracy of binocular depth perception, and performance on visually presented arithmetic tasks, all as a function of the amount of illumination provided.

Young adult male subjects, rigorously screened so that they constituted groups with excellent visual abilities, served as subjects. They were tested on dial-reading tasks and other visual perceptual tasks. A brightness range of 0.005 to 6.0 ft-L was used. For each task there was found a critical brightness level at approximately 0.01 to 0.1 ft-L, depending on the task. At brightnesses below this level visual performance was increasingly impaired; above this level in-

Presented on May 2, 1951, at the Society's Convention Screen Viewing Factors Symposium, at New York, by S. D. S. Spragg, University of Rochester, Rochester 3, N.Y.

*The research reported here has been carried out on a research contract between the University of Rochester and the Air Materiel Command, U.S. Air Forces. The experiments described have been reported in the following memorandum reports and technical reports issued by the Air Materiel Command: MCREXD-694-21 (October 1948); MCREXD-694-21A (Dec. 1948); TR 6013 (Nov. 1950); and TR 6040 (Nov. 1950). Research articles describing these studies will also be forthcoming in the *Journal of Psychology.*

creases in brightness produced little or no improvement in visual performance.

These findings suggest that for the night-time operation of equipment, and also for the viewing of complex visual stimuli at low illumination levels, brightness values should not be allowed to fall below 0.05 to 0.1 ft-L; on the contrary, they should be kept safely above this critical level in order to insure adequate visual perception.

Introduction

Instrument dials must often be read rapidly and accurately under conditions in which it is desirable to provide no more than the minimum amount of illumination necessary for the efficient performance of the task. Such conditions are found, for example, in the airplane cockpit during night flying. It has seemed desirable in the night operation of military aircraft and, perhaps to a somewhat lesser extent, for commercial aircraft, to attain and preserve as much dark adaptation on the part of the pilot and copilot as is feasible.

This demand has posed the persistent problem of the amount and nature of illumination which will best meet the requirements of the situation. Taken separately, the ideals are incompatible. On the one hand it would be desirable to flood the cockpit with a high level of white (incandescent) light. Studies of visual acuity, speed and ease of reading and performing other visual tasks, subjects' stated preferences, etc., have frequently concluded with recommendations for ambient illumination from 15–20 ft-c to 100 ft-c or even more.

On the other hand, it would be desirable to have no light or practically no light in the cockpit, so that pilot and copilot can achieve and maintain maximum dark adaptation and thus be better equipped to see and recognize other aircraft, mountains and other aspects of the terrain, etc.

A practical solution to the problem will obviously be a compromise between these two conditions. It will involve a determination of the effectiveness of visual performance under a range of intensities and spectral distributions of illumination which will: (a) permit satisfactory performance of visual perceptual tasks inside the cockpit (reading dials, etc.); and (b) maintain a level of dark adaptation sufficient for the pilot and copilot to deal adequately with visual stimuli coming from outside the cockpit.

As a beginning in a series of studies designed to contribute toward the solution of the problem, our project has undertaken certain experiments attempting to relate visual performance (as indicated by the speed and accuracy of reading dials) to the illumination provided.

Although speed and accuracy of dial reading constitute primarily a complex *perceptual* task rather than a simple *acuity* function, available information on the relationship between acuity and illumination is relevant in that it may suggest the general nature of the function as well as set a lower limit to performance.

The early study of König, as well as other more recent studies, indicated that acuity varies as the logarithm of illumination intensity, with the implication that even at high illuminations an increase in illumination will produce some increment of acuity.

Other workers, however, have reported that visual acuity increases with illumination increase only up to a relatively modest level (such as 10 or 20 ft-c) and that the increase in acuity is hardly noticeable beyond this range.

A great many recent studies, both military and civilian, have concerned themselves with factors determining acuity and other characteristics of visual performance, as a function of illumination level, in a variety of task situations. This literature has been surveyed, with differing emphases, by Fulton and his co-workers,[1] by Lawrence and Macmillan,[2] by Smith and Kappauf,[4] and others.

Fig. 1. A sample bank of dials, 2.8-in. diam, 100 × 10 scale.

There is still need, however, for a relating of specific visual perceptual performances, such as dial reading, to a systematically varied range of illumination values. That is the aim of the present study.

Procedures and Results

Subjects were cone dark-adapted to the illumination level being used and were then required to read banks of photographically reproduced instrument dials as rapidly and as accurately as possible. Figure 1 shows a typical bank of 12 dials. It will be noted that the scale is in ten-unit steps; thus, subjects have to interpolate to read to the nearest unit. Dials were 2.8 in. in diameter.

Two incandescent lights at about 2400 K were used as sources. They were mounted in cans and the illumination was controlled by means of ground-glass filters and accurately drilled apertures in interchangeable brass plates placed in the optical axis. A viewing distance of 28 in. was used.

Twenty young adult males who passed a rigorous visual screening were used as subjects. Preliminary practice on the task was followed by formal trials.

On the formal trials each subject read 10 cards of dials at each of five brightness levels. Time was recorded by the experimenter's starting the timer after the subject read the first dial and stopping it after he read the eleventh dial. The first and last dial readings in each card were eliminated from both the time and error data because of their relative unreliability. Thus, the data for each subject consist of 100 dials read at each of five brightness levels.

The levels of illumination were chosen as a result of exploratory experimentation which indicated that a rather sharp change in the difficulty of the dial-reading task occurs at a brightness of about 0.02 ft-L. For this experiment, therefore, two values were chosen which would closely bracket the suggested transition level, another value at slightly above cone threshold for the cone dark-adapted eye, one at 6.0 ft-L, and one at an intermediate level. The values selected were: 0.005, 0.018, 0.022, 0.296, and 6.0 ft-L.

Brightness measurements were made with a Macbeth Illuminometer used in the subject's position, and directed against an 11 × 14 in. sheet of unexposed but fixed photographic paper from the same stock as that of the dial reproductions.

A counterbalanced sequence of bright-

Table I. Dial-Reading Performance as a Function of Task Brightness (2.8-in. Dials; N = 20 Subjects)

Brightness, ft-L	No. (and %) of readings in error in reading 100 dials	Standard deviation	Mean reading time per dial, in seconds	Standard deviation
0.005	67.3	10	2.84	.93
0.018	59.9	14.1	2.64	.74
0.022	30.1	8.1	1.52	.21
0.296	27.8	5.5	1.33	.21
6.0	27.8	4.4	1.30	.22

ness levels was employed. Subjects completed the experiment in two sessions, several days apart. They were given no knowledge of results; that is, they were not told the correct readings, nor whether their readings were correct or wrong.

Table I summarizes the mean error frequencies and the mean total times. Each point is based upon 100 dials read by each of 20 subjects, therefore, upon 2000 readings.

Variances for subjects and for brightness levels were significant at the 1% level. An analysis by the "t test"* showed that, both for error frequency and for time, all differences that crossed 0.02 ft-L were significant at the 1% level, while no difference that does not cross this brightness value is significant at the 1% level. In fact, only one of them (error frequencies at 0.005 and 0.018 ft-L) is significant at the 5% level.

The error-frequency data are summarized graphically in Fig. 2 (results for 2.8-in. dials), and the data for average reading time, in Fig. 3 (also 2.8-in. dials). Inspection of these two figures shows that the error curve and the time curve are highly similar. By both measures, there is strong evidence that in this rather complex visual perceptual task there is marked improvement at about 0.02 ft-L and relatively little improvement thereafter, at least up to 6.0 ft-L. We have made informal observations indicating no significant improvement at levels considerably higher than this.

Because of the fact that these findings are based on fairly large dials with widely-spaced scale divisions, it was decided to repeat the experiment with smaller dials and finer scale-division spacings. Accordingly, a second experiment was run, using dials which were 1.4 in. in diameter and had scale marks for every unit instead of every ten units, as in the above experiment.

The general procedures were the same as in the preceding experiment. Ten subjects were used and (because of the setup demanded by another concurrent study) brightness levels of 0.005, 0.01, 0.05, 0.1, and 1.0 ft-L were employed.

The results of this experiment are summarized in Table II which shows the proportional error frequency and the mean time required, for the several brightness levels. It will be seen that there is a sharp improvement in performance up to 0.1 ft-L and relatively slight improvement above that level.

The results for the 1.4-in. dials are shown graphically in Figs. 2 and 3, in which are plotted the error data and the time data. Again it will be seen that

---

* The t test is a statistic frequently used to evaluate the probable genuineness of an obtained difference between two sets of means. For example, a difference which the t test shows to be "significant at the 1% level" is a difference which would have occurred by chance fluctuation only 1 time in 100, and therefore can be regarded with a high degree of confidence as a genuine difference (cf. the sections on small sample statistics in a standard statistics textbook).

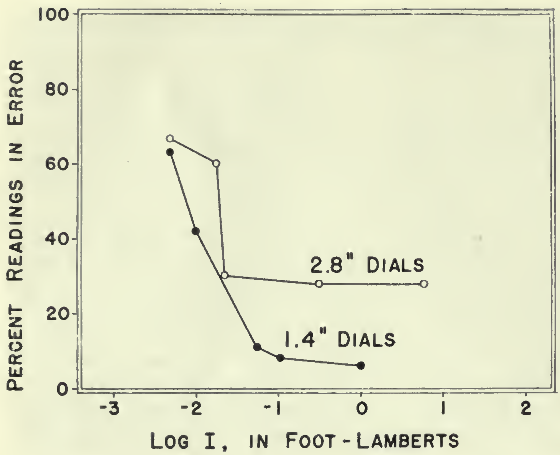


Fig. 2. Frequency of errors in reading large dials (2.8-in. diam, 100 × 10 scale) and small dials (1.4-in. diam., 100 × 1 scale) as a function of brightness.

Table II. Dial-Reading Performance as a Function of Task Brightness (1.4-in. Dials; N — 10 Subjects)

Brightness, ft-L	No. of readings in error in reading 50 dials	Standard deviation	% of readings in error in reading 50 dials	Mean reading time per dial, in seconds	Standard deviation
0.005	31.3	8.0	62.6	3.45	1.33
0.01	20.8	7.8	41.6	2.79	0.66
0.05	5.7	4.0	11.4	1.77	0.21
0.1	3.9	2.8	7.8	1.71	0.24
1.0	3.2	2.1	6.4	1.55	0.21

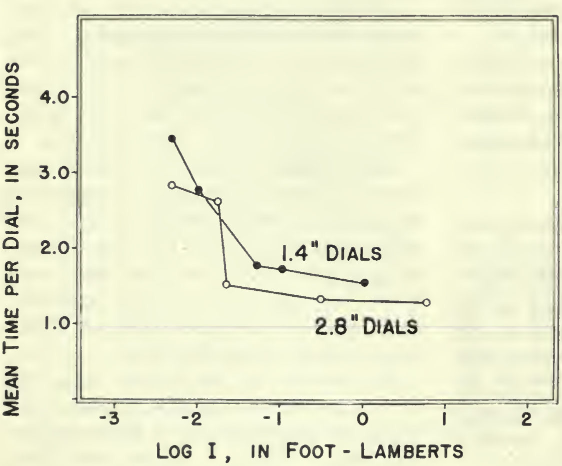


Fig. 3. Mean time in seconds required to read large dials (2.8-in. diam, 100 × 10 scale) and small dials (1.4-in. diam, 100 × 1 scale) as a function of brightness.

performance improves markedly with increased brightness up to the 0.01–0.1 brightness level, but there is little improvement in performance above this level.

Inspection of Figs. 2 and 3 permits a comparison of results for the larger, coarse-scaled dials and the smaller, fine-scaled dials. It will be seen that: (a) at the lowest brightness level, performance is about the same, approximately two-thirds of the readings being in error in each case; (b) between 0.01 and 0.1 ft-L there is rapid improvement in both cases, and relatively little improvement above this level; and (c) that performance levels off at a poorer performance value for the large dials, with their widely-spaced scale divisions and the necessity for making interpolations, than it does for the smaller, more finely-spaced dials where no interpolations are necessary.

The same comparison can be made for time scores. Very little difference in results is to be noted here. If anything, performance is somewhat slower with the smaller, finely-spaced dials.

These results seem to indicate that there is a critical brightness level below which subjects find it difficult to perform this dial-reading task, as shown by relatively slow responses and greater frequency of errors. Above this level, the task becomes suddenly much easier, responses are quicker, and frequency and magnitude of errors much less. Further increases in brightness, however—at least up to 6.0 ft-L and very probably indefinitely—produce no further increments of performance. It seems as though once a subject has been given just enough brightness to perform this task with ease, brightness is no longer a significant variable.

This finding is in interesting contrast with König's classical curve relating acuity to brightness, and to the findings of certain recent investigators that acuity continues to increase even at very high brightness levels. Other workers, whose data indicate that acuity ceases to increase beyond a certain brightness level, have usually reported that their curves do not flatten out until about 5 to 10 ft-c of illumination.

No real discrepancy exists between such findings and the present results. Our data were taken in a complex perceptual task in which adequacy of performance is a function not only of acuity and contrast, but also of speed and accuracy in making the complex judgment which an interpolation represents. Since we are dealing with a task which is far more complex than a simple resolving power function, the lack of close correspondence between our results and the earlier acuity studies should not be disturbing.

I wish to mention some further studies in this general area which were carried out by Dr. Milton L. Rock of our project.[3] The problem undertaken was a systematic examination of the adequacy of performance of four rather widely-varied visual perceptual tasks over a range of low photopic brightnesses. The tasks chosen were: (1) magnitude of judgment error in a conventional Müller-Lyer illusion figure; (2) absolute threshold for perception of movement of an alternately black and white striped field; (3) accuracy of binocular depth perception in a modified Howard-Dolman type apparatus; and (4) performance in a series of visually presented addition tasks (a 3-digit number followed by a 2-digit sum, and the subject is required to state whether it is or is not the correct sum of the first three digits). These four tasks were chosen to represent a rather wide range of visual perceptual tasks as far as complexity is concerned.

Subjects, screened visually as in our previous experiments, were tested on these tasks at the following brightness levels: 0.005 (which is just above cone threshold for the cone dark-adapted eye), 0.01, 0.05, 0.10, and 1.0 ft-L. The viewing distance was 28 in. for each task.

I am not going to describe the details of these four experiments, but shall

attempt to indicate briefly the principal results.

For the Müller-Lyer figure, mean errors in judgment decreased sharply as brightness increased from 0.005 up to 0.05 ft-L, but there was practically no improvement for brightnesses higher than this value.

For the experiment on absolute motion threshold performance improved sharply as brightness was increased from the lowest values up to 0.1 ft-L, then only slightly from there up to 1.0 ft-L.

For the depth perception experiment, increased brightness brought a marked increase in accuracy of judgments from the lowest brightness up to 0.05 ft-L and little or no increase above this level.

Finally, in the addition task, improvement in performance was marked from the lowest level up to 0.05 ft-L, then stayed at essentially the same value for the two highest brightness levels.

For all four of these visual tasks, when performance is plotted against brightness level we find *rapid* improvement in performance as brightness is increased—up to a certain level and beyond this level, increases in brightness bring relatively slight increments of performance. This critical level seems to be between 0.01 and 0.05 ft-L for the Müller-Lyer, the depth perception, and the addition tasks, and between 0.05 and 0.1 ft-L for the motion threshold task. It will be recalled that in the dial-reading experiments this critical value was estimated to be about 0.02 ft-L in one experiment and between 0.01 and 0.05 ft-L in the other.

Conclusions

Evidence seems to be accumulating that for visual tasks of a perceptual nature (in contrast to simple acuity functions) there is a critical brightness level (probably between 0.01 and 0.1 ft-L, depending on the task) below which subjects find it difficult to perform the task, and performance is relatively poor, while above this value the task becomes much easier, responses are faster and more accurate, and additional increments of brightness make relatively little difference.

From a practical standpoint, the findings from these studies indicate that in visual perceptual situations where maximum performance is required with a minimum of brightness (in order, for example, to conserve dark adaptation), great care should be taken that the brightness level not be allowed to drop below about 0.05 to 0.1 ft-L.

These findings have implications for the night operation of equipment, e.g., aircraft, and also for the viewing of complex visual stimuli at low levels of illumination. If the visual material to be perceived has a brightness safely above 0.05 ft-L, then the visual perception of that material will be as rapid and as accurate as it would be if the brightness were at higher levels (at least up to 6 ft-L, and possibly indefinitely). Our results do not, however, provide data bearing on the problems of: (1) fatigue effects of long-continued viewing under these conditions; or (2) individual preferences. Further research is needed to supply information here.

References

1. J. F. Fulton, P. M. Hoff and H. T. Perkins, *A Bibliography of Visual Literature, 1939–1944*, Geo. Banta, Minasha, Wis., 1945.
2. M. Lawrence and J. W. Macmillan, *Annotated Bibliography on Human Factors in Engineering Design*, Aviation Br., Research Div., BuMed, U. S. Navy, 1946.
3. M. L. Rock, "Visual performance as a function of low photopic brightness levels," USAF, Air Materiel Command, TR 6013, Nov. 1950.
4. W. M. Smith and W. E. Kappauf, "Studies pertaining to the design and use of visual displays for aircraft instruments, computors, maps, charts, and tables," USAF, Air Materiel Command, TSEAA-694-1G, May 1947.
5. S. D. S. Spragg and M. L. Rock, "Dial reading performance as related to illumination variables. I. Intensity,"

USAF, Air Materiel Command, MCR-EXD-694-21, Oct. 1948.

6. S. D. S. Spragg and M. L. Rock, "Dial reading performance as related to illumination variables. III. Results with small dials," USAF, Air Materiel Command, TR 6040, Nov. 1950.

Discussion

Ben Schlanger: Was consideration given to the time factor, that is, do you know the effect after one or two hours of viewing?

S. D. S. Spragg: Our experimental session typically lasted forty to forty-five minutes and there was no significant change in performance toward the end of this period. Our data, however, do not contribute anything to what might be called fatigue studies. Our results have no implications for continuous viewing that may extend for several hours under these conditions, although there are relevant studies which show that visual fatigue in tasks of this sort is almost impossible to demonstrate. Dr. Brian O'Brien has shown that, and Carmichael and Dearborn have also shown it for periods up to, maybe, seven or eight hours.

O. W. Richards: Your work was done at relatively close distances. I was wondering if you have any information that would apply to farther distances where convergence and other factors wouldn't enter. In other words, do you view this as entirely a general factor or do you think it involves other problems?

Dr. Spragg: These experiments were all carried out at 28-in. distance which is the standard distance recommended for research on visual performance, or problems, in the cockpit, as specified by the Visual Standards Committee of the NRC Vision Committee, and it is an extrapolation to generalize from our data to distant conditions. The details of our visual task were never much less than five minutes of angle and were all viewed at 28-in. distance.

Anon: Dr. Spragg, can you tell me, regarding visual acuity and low brightness, what effects of color, primarily red, were shown in the study?

Dr. Spragg: We have carried out two studies on dial reading under different qualities of illumination, using Corning sharp cut-off filters. I didn't report them here because I wanted to restrict this report primarily to the brightness problem. I might say, very briefly, that, as you suspect, we're interested in the red and yellow region because that region of the spectrum is important for maintenance of dark adaptation. We found that if we took a good deal of care to make the color values equal, as determined by heterochromatic color matching, so that we could say that we had red at 0.1 ft-L, red at 0.01 ft-L, and also yellow and other colors at the same value, that color made no difference if we stayed above this critical level of about 0.02 ft-L; that is, performance was neither worse nor better with red, orange or yellow than it was with green. However, if we got below 0.02 ft-L, color still didn't seem to make very much difference, but red was worse than the other colors viewed. Thus, if red illumination is used for night operations and for reading instruments, it would seem more than ever crucial to keep the red illumination above this 0.02 ft-L level.

Surround Brightness: Key Factor in Viewing Projected Pictures

By SYLVESTER K. GUTH

The lighting of areas where projected pictures are viewed presents a number of specialized problems to the lighting engineer. However, these specialized problems involve factors of lighting design rather than any particularly unusual visual factors. Basically, projected pictures are visual tasks upon which the eyes and attention of the viewers are concentrated for extended periods. Since the viewing of projected pictures is a seeing task, two distinct objectives are suggested: (1) providing maximal visibility of the task; and (2) providing maximal visual comfort and ease of seeing. These are fundamental objectives that must be satisfied in order to obtain optimal seeing conditions in any visual situation. This paper is confined chiefly to the second objective and to those factors which determine whether the area in which projected pictures are viewed is visually satisfactory. The screen is introduced only insofar as it influences or is influenced by the environmental factors.

THE BRIGHTNESS characteristics of various portions of the visual field surrounding the central or task area are of overwhelming importance in providing a comfortable visual environment.[1] These brightnesses, and their relationships to the brightnesses of the task, contribute favorably or unfavorably to the seeing conditions. They may influence directly the visibility of the visual task, or their effects may be more subtle and result in decreased ease of seeing. Obviously, both effects may be and often are produced simultaneously, especially when prolonged seeing is involved.

The difficulty of obtaining adequate auditorium brightnesses in theaters has often resulted in minimizing the importance of the surround brightnesses for ability to see and comfort of viewing. The lack of reports of discomfort has been used as one of the principal arguments for considering that there is nothing wrong with the existing viewing conditions. Such lack of complaints should merely be taken as the audience acceptance of what it is used to, just as it has done in many other fields. Since the motion picture is a visual task, the consideration of light and lighting can and should include the same factors that apply to other visual situations.

Presented on May 2, 1951, at the Society's Convention Screen Viewing Factors Symposium, at New York, by Sylvester K. Guth, General Electric Co., Nela Park, Cleveland 12, Ohio.

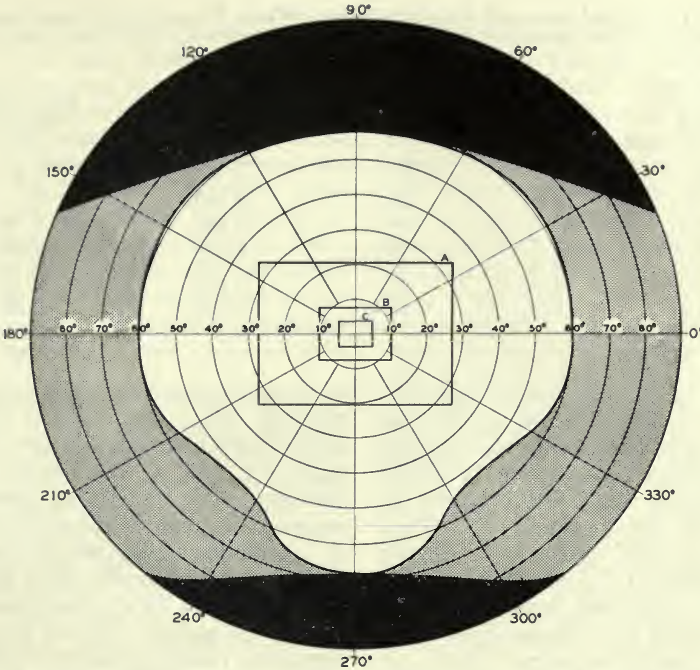


Fig. 1. A diagrammatic representation of the monocular and binocular visual fields. The portions occupied by a motion picture screen when viewed at three distances, corresponding to the screen width *W*, 3*W* and 5*W*, are illustrated by rectangles A, B and C, respectively. Shaded areas (right and left) represent portions of the visual field seen only by the right and left eyes, respectively. Unshaded area represents that portion of the visual field seen by both eyes.

Basic Considerations

In order to understand the importance of the surrounding conditions in the central field, it may be well to consider briefly the relative magnitudes of the two areas. The angular extent of the entire binocular visual field varies with the individual physiognomy and averages about 200° horizontally and 130° vertically, and is approximately elliptical in shape. The limits of various portions of the visual field are illustrated in Fig. 1. The unshaded area indicates the portion of the visual field in which objects can be seen by both eyes. The two shaded areas on the right and left represent those portions of the visual field that can be seen only by the right and left eyes, respectively.

The Task Area. A visual task usually occupies a limited region in the central portion of the visual field and its apparent or visual size is a function of the distance from which it is viewed. A motion picture screen, for example, appears large or small depending upon whether it is viewed from the front or rear of a theater. The three rectangles superimposed upon the visual field, illustrated in Fig. 1, represent a motion picture screen viewed from three different positions in an auditorium. In order to be applied generally to any size screen, the viewing distance is expressed in terms of the screen width, *W*. Thus, a screen viewed at a distance corresponding to the screen width, *W*, is represented by rectangle A, the angular extent of which

Table I. The Visual Size and Area of a Screen When Viewed at Various Distances

Viewing distance in screen widths	Angular subtense of screen degrees Width	Height	Solid angle subtended by screen steradians	Per cent of visual field
W	53.1	41.1	0.75	15.0
$2W$	28.1	21.2	0.19	3.8
$3W$	18.9	14.3	0.083	1.7
$4W$	14.3	10.7	0.047	0.94
$5W$	11.4	8.6	0.030	0.60
$6W$	9.5	7.2	0.021	0.42
$7W$	8.2	6.1	0.015	0.30
$8W$	7.2	5.4	0.012	0.24

is about 53° horizontally and 41° vertically. If the screen is viewed from the rear part of an auditorium, or a distance of $5W$, it occupies a much smaller portion of the visual field and may be represented by rectangle C. When viewed at this distance, it extends approximately 11° horizontally and 8° vertically. The intermediate rectangle B corresponds to a viewing distance of about 3 times the screen width. It should be noted that in some theaters a screen may appear even smaller than the one indicated by C.

It is seen that even when the screen is viewed from a short distance, it occupies a relatively small portion of the binocular visual field. The importance of the peripheral regions can be emphasized by considering the relative areas involved. A convenient and expressive unit of apparent area is in terms of the solid angle, Q, in steradians,* subtended by a surface which combines the actual projected area with the distance from the eye to the center of the surface. Thus, the relative extent of a surface can be expressed as a percentage of the total solid angle subtended by the entire binocular visual field which is approximately 5 steradians. The solid angle subtended by a motion picture screen is dependent upon its actual size and the distance from which it is viewed, and both of these may vary over a considerable range. However, when the viewing distance is expressed in terms of the screen width, W, it is possible to illustrate the ranges of apparent sizes of screens as in Table I. It is seen that as the viewing distance increases, the angular extent of the screen diminishes rapidly between W and $2W$, and progressively more slowly for distances greater than $2W$. A more significant comparison is the solid angle in steradians subtended by the screen and the per cent of the visual field occupied at various viewing distances. Except for those who sit very close to the front of the theater, the screen occupies less than about 4% of the visual field, and for the average viewer less than 1%. Thus, it is obvious that the magnitude of the peripheral region of the visual field makes it extremely important to the viewer of projected pictures. Consequently, this area cannot be neglected when designing the lighting for comfortable seeing conditions.

When it is considered that the viewing of projected pictures involves a dynamic rather than a static visual situation, the area immediately surrounding the screen becomes even more important. In order to see all of the picture details, the eye may rove over the entire screen, the angular movement depending upon the viewing distance. Thus, at times, the

* The solid angle, Q, in steradians is equal to the projected area of a surface divided by the square of the distance from the surface to the eye; i.e., $Q = \frac{A}{D^2}$.

line of vision may be directed toward the edge of the screen and then the screen surround is close to the line of vision. For the longer viewing distances, a relatively small angular movement of the eyes will bring the screen surround into nearly direct view. Therefore, unless the surround brightness has been properly adjusted, the viewer is faced with a considerable variation in adaptation brightness which can do nothing but detract from his pleasure and comfort by providing an undesirable visual environment.

When designing lighting, it is necessary to consider the various characteristics and requirements of the visual task. While the viewing of projected pictures usually involves prolonged periods, the task involves some factors that are different from those pertaining to other tasks such as reading. Much of the information or the story is obtained by words and the gestures, facial expressions and actions of the performers. Therefore, visual acuity is less important than the discrimination of a wide range of brightness contrasts. The viewer is not confronted with the problem of resolving small details near the threshold in size. However, while discrimination of the characteristics of the visual task may not be critical, the eyes and attention are focused steadily with but brief respites.

Adaptation Brightnesses. In any specific situation, the desirable surround brightness is dependent upon the brightness level to which the eyes are adapted. Therefore, it is necessary to determine the relationship between the picture brightness and the surround brightness. However, the former varies over a considerable range, depending upon projection-equipment, theater and screen sizes, film characteristics, etc. It may range from a very low level for the opaque projectors used in educational work to the high levels obtained with slide projectors. Nevertheless, it is possible to develop a concept in terms relative to the screen brightness obtained with the projector running without film. Furthermore, since a motion picture, or any sequence of projected still pictures, presents a continuously variable brightness pattern, it is difficult to arrive at any specific brightness that can be considered representative of all conditions. One method is to record the variation in integrated or average-picture brightness for a typical film and to determine the mean brightness over an extended period of time. However, the range of average brightnesses, especially the minimum values, are of importance.

A typical record for a black-and-white film is shown in Fig. 2. The film used included photographs of almost completely white areas to extremely dark night scenes and can be considered to be representative. In order to make the record of Fig. 2 more universal in its application, the ordinate is shown as per cent of clear-screen brightness. Thus, it is a simple matter to convert the relative values to actual brightnesses. For example, in terms of the clear-screen brightness, the maximum average brightness recorded for the lightest scene was about 25%; the minimum brightness was 1.0%; and the mean value for the entire film was about 10%. Therefore, when the clear-screen brightness is 15 ft-L, the picture brightnesses are approximately 3.8 maximum and 0.15 minimum with a mean of 1.5 ft-L. It is interesting to note that these values compare favorably with those obtained by Logan.[2]

A similar record taken with an industrial color film gave a mean brightness of about 5% of the clear-screen brightness with maximum and minimum values of 16% and 1%, respectively. For a clear-screen brightness of 15 ft-L, these brightnesses are a mean value of 0.75, a maximum of 2.4, and a minimum of 0.15 ft-L. Obviously, there will be quite a wide variation among films. However, these brightnesses appear to be within the range of what is obtained in representative theaters.

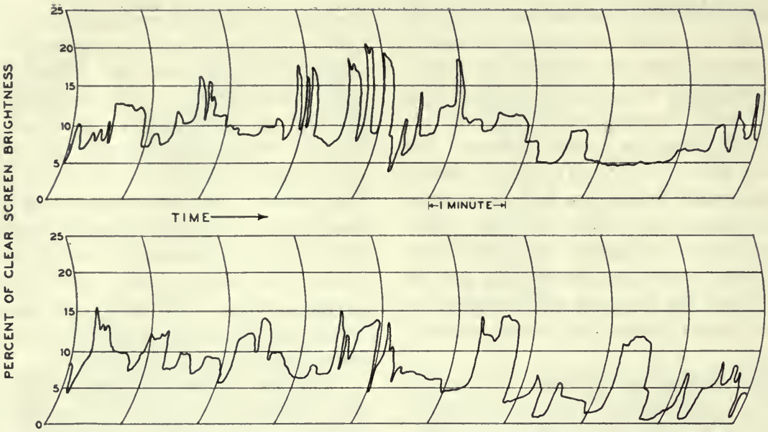


Fig. 2. A record illustrating the variation in integrated or average brightness of a typical motion picture in terms of the clear-screen brightness.

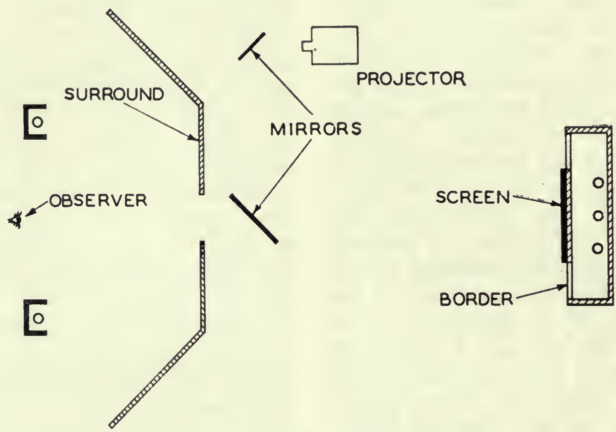


Fig. 3. The experimental arrangement used for determining the desired border and surround brightness when viewing projected pictures.

Experimental Arrangement

In order to isolate and to control independently the brightnesses of the various areas in the visual field, the experimental arrangement illustrated in Fig. 3 was adopted. This is a modified scale model of a theater in which 1 in. equals 1 ft. The screen was 20 in. wide, thus corresponding to a 20-ft screen. The observers were located at a distance of six times the screen width from the plane of the screen, or a distance of 120 in. Immediately surrounding the screen was a transilluminated diffusing glass, the brightness of which could be adjusted by the observers. This area corresponds generally to the area on a stage surrounding a motion picture screen and is termed the screen border. Between the observer and the screen was a panel, the brightness of which could be independently controlled. The observer viewed the projector screen through a rectangular aperture in the panel. This

aperture was of such a size that the trans-illuminated screen surround could be seen by the observer. This arrangement enabled control of the two surround brightnesses without permitting any stray light to reach the screen. While this experimental arrangement does not duplicate exactly the visual situation of a theater, it is considered to be sufficiently typical for the present purposes.

In the present investigation, which was intended only to be exploratory, clear-screen brightnesses ranging from 1.1 to 60 ft-L were used. These include brightnesses that are obtainable with various types of projection equipment such as highly efficient projectors used at a relatively short projection distance, opaque projectors, slide-film projectors, etc. The brightnesses were obtained with a standard 16-mm projector in which were used lamps of 200, 300 and 750 w for screen brightnesses of 11, 25 and 60 ft-L, respectively. By means of a neutral-density filter, these brightnesses could be reduced to one-tenth of these values for a lower range of 1.1, 2.5 and 6 ft-L. These clear-screen brightnesses corresponded to mean picture brightnesses ranging from 0.1 to 6 ft-L.

The observers viewed the motion picture and, for each value of clear-screen brightness, adjusted the brightness of the border until they deemed it most desirable for viewing the projected picture. Their judgment was based upon viewing comfort and upon the appearance of the projected pictures. A group of five observers made a series of five observations on each of two sittings for the various screen brightnesses. Each observer was permitted as long a period to make each observation as he felt necessary. Each series of observations included representative portions of the motion picture.

Experimental Results

Influence of Screen Brightness. The average brightnesses of the border selected by the observers are plotted in Fig. 4 for clear-screen brightness ranging from 1.1 to 60 ft-L. The observed data for viewing motion pictures are represented by the open circles. These points can be represented by a straight line, indicating a linear relationship between the logarithms of the clear-screen brightness and the selected border brightness. Since the average-picture brightness is approximately one-tenth of the clear-screen brightness, the scale at the top of Fig. 4 illustrates the average-projected-picture brightnesses for corresponding clear-screen brightnesses. The picture brightness is a more representative value, since it can be considered as the brightness to which the eyes are adapted.

A similar investigation was conducted with a typical black-and-white slide film. The solid dots indicate the average border brightnesses selected by two of the observers for four screen brightnesses, ranging from 1 to 20 ft-L. These values check very well with those obtained with motion pictures. In other words, the fact that the observer is viewing a still or motion picture does not seem to influence his decision regarding the most suitable border brightness. Similar results were obtained with a color film.

It was found that the surrounding screen brightness had no significant effect upon the selection of the border brightness, provided that it was equal to or less than the latter. None of the observers desired a zero surround brightness. The general preference was about one-half the border brightness. All who viewed the projected pictures in the experimental situation were unanimous in indicating that the border brightness was of greatest importance. Therefore, the following discussion is based primarily upon the border brightnesses selected by the observers for the various screen brightnesses.

The desirable border brightness is not a simple function of the clear-screen or average-picture brightness, but is exponential, and may be represented by:

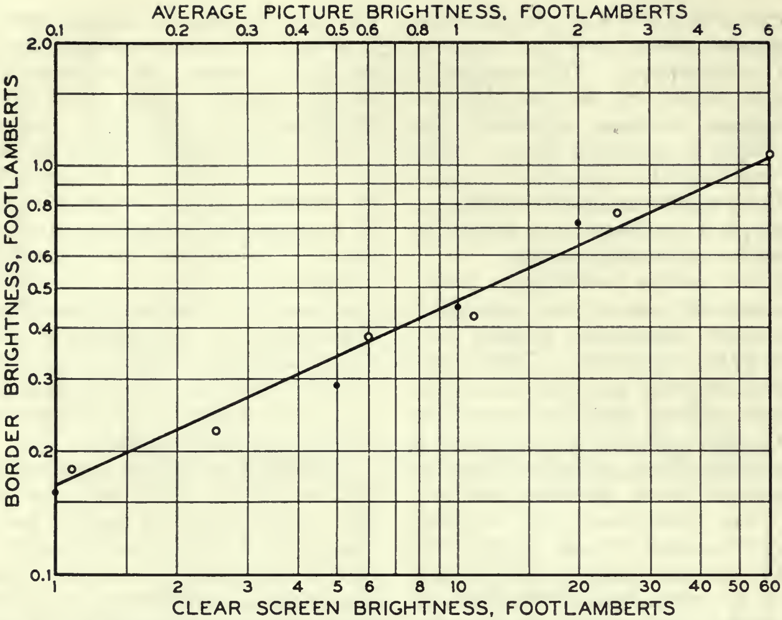


Fig. 4. The relationship between desired border brightness for various clear-screen and average-picture brightnesses. The open circles and solid dots represent observed values obtained with a motion picture and slide film, respectively.

$$B = 0.16\ S^{0.45} \quad (1)$$

or $$B = 0.46\ P^{0.45} \quad (2)$$

where B, S and P are the border, clear-screen and mean-picture brightnesses, respectively. A simple approximation is that the border brightness is equal to the square root of the screen (or picture) brightness multiplied by a constant. In terms of average-picture brightness, the desired border brightness is indicated to be about one-half of the square root of the picture brightness.

It may be of interest to compare the above equations with one developed from data obtained in an earlier investigation of comfortable brightness relationships in interior lighting.[3] The relationship between the brightness, B, of a light source and the brightness, F, of the adapting field was found to be:

$$B = 302\ F^{0.44} \quad (3)$$

In the three equations, the brightness of a light source or luminous area outside of the region of a visual task is expressed as a function of the brightness to which the eyes are adapted. The coefficient is dependent upon the criterion, the visual sensation being studied and other experimental factors. However, the similarity between the exponents is particularly significant and illustrates a common basis for the two investigations. Since most visual functions follow well-established laws and patterns, it should be expected that similar relationships would be obtained.

The ratio between the border and picture brightnesses is a variable one. For example, when the picture brightness is 0.2 ft-L (corresponding to a clear-screen brightness of 2 ft-L), the indicated border brightness is 0.22 ft-L. This is approximately equal to the average-picture brightness. However, when the picture

brightness is 2 ft-L, the desired border brightness is 0.63 ft-L or about one-third of the average-picture brightness. In other words, relatively lower border brightnesses are desired for higher picture brightnesses than for the lower picture brightnesses. This is understandable, since an important factor is the total luminous flux directed toward the eye by the area surrounding the screen. Furthermore, the eyes become progressively more sensitive to brightness differences as the adaptation brightness is increased. Therefore, relatively lower border brightnesses will be selected for the higher picture brightnesses. Nevertheless, these indicated desirable border brightnesses are considerably higher than those indicated by other investigators.[2,4]

It is emphasized that the technique used in this investigation eliminated the factor of stray light upon the screen. These relatively high border and surround brightnesses may be impractical in existing theaters. Nevertheless, these results do indicate that under ideal conditions, higher brightnesses are desirable. They should be obtainable in a properly designed auditorium.

Stray Light. In the usual auditorium, a limiting factor which governs the permissible surround brightness is the amount of stray light reflected upon the screen. Therefore, a brief investigation was made to determine the amount of stray light which would produce a just barely perceptible effect upon the picture quality. A small source of light, mounted on the rear of the surround screen, was variable and controlled by the subject. This source provided a variable amount of stray light upon the picture screen. The observer viewed the projected picture, simultaneously varying the amount of stray light until he deemed it to be a maximum without affecting the quality of the picture. This was investigated with two picture brightnesses. When the picture brightness was 0.50 ft-L (clear-screen brightness equal to 5 ft-L), it was found that a stray-light brightness of about 0.07 ft-L produced no effect upon the picture. For a picture brightness of 3 ft-L (30-ft-L clear-screen brightness) the stray light could be increased to 0.15 ft-L.

Referring to Fig. 4, it is seen that the border brightness for a picture brightness of 0.50 ft-L is 0.33. Thus, the stray-light brightness is about one-fifth of the border brightness. A similar ratio was found for the picture brightness of 3 ft-L, where the desired border brightness was 0.76 ft-L and the permissible stray light was 0.15 ft-L.

Color Film. A similar brief investigation was made with a color film. While the one used may not be exactly representative of the usual production films, it does make possible a qualitative appraisal of desired border and stray-light brightnesses. The average-picture brightness was found to be about 5% of the clear-screen brightness, which is half of the average-picture brightness of the black-and-white film. This is lower than that found by Logan,[2] whose measurements indicated a higher average-picture brightness for color film than for black-and-white film. The results obtained with two observers indicated that the border brightness desired when viewing the color film corresponded to that obtained for the black-and-white film. In other words, it appears that the border brightness is a function of the average-picture brightness and that viewing color pictures has no measurable effect upon the desired brightness.

On the other hand, it was found that stray light upon the screen was more effective for color film than for black-and-white film. For equal picture brightnesses, the maximum tolerable stray light for viewing color film was about one-half that found to be tolerable for black-and-white film. These results are logical and to be expected. The shading and blending of colors and their contrasts are important factors in the appearances of projected color pictures. On the other hand, a black-and-white

picture involves a range of neutral values which are merely shifted slightly to lighter tones by the stray light. For example, in the latter case, for an average-picture brightness of 1 ft-L, it is assumed that the white and black brightnesses are 5 and 0.05 ft-L, respectively. The tolerable stray light for this condition would be about 0.10 ft-L (one-tenth of the average picture brightness). Calculated values of contrast between the black and white areas without and with stray light are 99% and 97%, respectively. Similar calculations for other picture areas yield correspondingly small changes in contrast. In other words, the stray light selected as maximal tolerable produces too small a change in contrast to be significantly visually effective. Calculations for color pictures would be considerably more complex since they would have to involve a consideration of color change as well as a change in brightness. The former probably is the reason for a lower tolerance of stray light when viewing color pictures.

Conclusions

The relationships between average-picture brightness, border and surround brightnesses, and the stray light make it possible to predict or to predetermine the conditions that are expected to be most satisfactory in any theater. A simple rule would be to raise the border and surround brightness to the value that will not produce an excessive level of stray light upon the screen. Of course, the brightness of the border should not exceed that found desirable for the available average-picture brightness. For example, for a typical theater, if the clear-screen brightness is 10 ft-L and the average-picture brightness is 1 ft-L, the border brightness should be about 0.45 ft-L, but the stray light should not produce a brightness greater than 0.09 ft-L.

The values of border and surround brightnesses indicated by this investigation are somewhat higher than those published by others. Logan, for example, has suggested a surround brightness of 0.10 ft-L for an average-picture brightness of 1 ft-L.[2] This is about one-fifth of the value determined in the present investigation. Others have reported surround brightnesses of the order of 0.05 ft-L to be desirable.[4] A review of the limited literature on the subject indicates that most of the values have been based upon empirical attempts to apply data obtained with experimental and environmental conditions that are not directly applicable to the viewing of projected pictures. Nevertheless, there is the common conclusion that some brightness is required in motion picture theater auditoriums.

Another important aspect of brightness in viewing areas is the sources which produce the low brightnesses on the border, walls, ceiling and floors. At the low visual adaptation levels these sources and any other areas of relatively high brightness must be kept to a minimum in order for them not to be distracting or even uncomfortable. A method has been developed for determining the tolerable brightnesses of sources, such as aisle lights, bright areas of walls, fixtures, etc. In essence, they must be reduced in brightness and area so that their visibility does not compete with the visibility of the projected picture. The permissible brightnesses of such areas is a function of the size of the source or bright wall area, its position in the visual field and the average-picture brightness. This method has been described in detail elsewhere.[3,5] While it was not developed for the projected picture problem, the general principles involved should be applicable to any visual environment.

There are other factors which may have an important influence upon the final accepted or desirable surround brightnesses. These include, especially, the psychological factors which govern the mood of, and impressions gained by

the viewers. In other words, the actual brightness level used should enhance the illusions being created by the motion picture. Theoretically, at least, the viewer is asked to place himself in the actual situation being created on the screen, be it the hot sunlit desert or the dark mysterious passageways of a haunted house. Environmental brightnesses must enhance and not destroy these effects. Thus, there are many aspects to the problem of providing the surround brightnesses for viewing the projected pictures. Ultimately, all of them must be investigated before their individual importances in any situation can be evaluated. Perhaps a semi-variable control system will be necessary. Whatever is required should be determined by carefully conducted investigations rather than empiricisms or opinions.

It is emphasized that the investigations and results presented in this paper are exploratory. A primary purpose was to develop a technique that would enable observers to make considered appraisals of the environmental brightnesses in an experimental situation that approximated actual viewing conditions. Since the observers used in these studies have been used in a number of earlier investigations, and were selected as being representative, it is believed that the brightnesses selected by them are indicatory of the levels that are desirable.

References

1. Matthew Luckiesh, "Brightness engineering," *Illum. Eng.*, vol. 39, pp. 75–92, Feb. 1944.
2. H. L. Logan, "Brightness and illumination requirements," *Jour. SMPE*, vol. 51, pp. 1–12, July 1948.
3. Matthew Luckiesh and S. K. Guth, "Brightnesses in visual field at borderline between comfort and discomfort (BCD)," *Illum. Eng.*, vol. 44, pp. 650–670, Nov. 1949.
4. L. A. Jones, "Interior illumination of the motion picture theatre," *Trans. SMPE*, pp. 83–96, May 1920.
   B. O'Brien and C. M. Tuttle, "An experimental investigation of projection screen brightness," *Jour. SMPE*, vol. 26, pp. 505–517, May 1936.
5. Sylvester K. Guth, "Comfortable brightness relationships for critical and casual seeing," *Illum. Eng.*, vol. 46, pp. 65–75, Feb. 1951.

Discussion

O. W. Richards: I was wondering if you'd care to make any comment on how the color temperature of your surround lighting should compare with the border lighting?

S. K. Guth: In this investigation we were not particularly concerned with the spectral quality of the border lighting. However, we did use filters over the lamps used for the border brightness and used special combinations of fluorescent lamps for the surround brightness so that the color would be as unobtrusive and neutral as possible. Both could be considered so-called white and differences were inconspicuous. Any significant difference between, for example, the relatively lower color temperature of filament lamps (3000 K) and the relatively higher color temperature of daylight (6000 K) would have to be investigated. I would think that for a typical black-and-white film the color of light for the border and surround is not nearly as important as it obviously would be for color film. It may be a function of the actual brightness to which the surround should be adjusted for optimal viewing conditions. It is possible that one color temperature will be desired for higher screen brightnesses, and another one for lower screen brightnesses.

Anon: I recall from several years ago that the Windermere Theater, on the Cleveland East Side, was a theater where auditorium illumination was on the high side compared with most theaters. Possibly you people have done some experimental work there. I was wondering if there were any theaters that you could point out or that you had in mind that do use a border brightness of somewhere around the figure that you quoted, that is, where, for example, with 10 ft-L from the screen you had a border brightness of about 0.5 ft-L?

Mr. Guth: I am not familiar with any

such theaters. Since I started thinking about this problem I have been very conscious of the border brightnesses and the surround brightnesses, but I haven't come across any that I would judge were quite that high. I have seen some of the theaters in Cleveland that seemed to have a somewhat higher border brightness than others, but I made no measurements.

Anon: I was thinking that it might be very interesting to actually see something like that, and if you could convince some neighborhood theater in Cleveland, they would experiment a little bit and I am sure there would be enough people in Cleveland glad to work with you on that.

Mr. Guth: It would be interesting to make such experiments. Ultimately, only full-scale investigations can give us the final answer regarding the desirable surround and border brightness.

Ben Schlanger: We have designed several theaters in which we have relatively high levels of illumination around the screen, by the synchronous method. Mr. Logan has had the opportunity to see one of them and I believe he refers to this example in his paper.

W. W. Lozier: I have two questions, Mr. Guth. One, your observations were all made at a point corresponding to the back of the average theater. I wonder how they might be changed for a person sitting up in the middle of the auditorium area or toward the front?

Mr. Guth: I don't have any actual data on that particular phase of it, though several observers did sit at various distances from the screen for a few observations. We found that with shorter observation distances the surround brightness became less important. However, the border brightness still remained important because of its proximity to the picture area. This brief test indicated that the border brightness was about the same, regardless of the observation distance. However, this should be confirmed by observation distances.

Dr. Lozier: Another question—you relate this border brightness that the observer shows to the average-picture brightness. Do you have any information on what their preference was on picture brightness? Was any preference expressed on that?

Mr. Guth: This is, of course, another aspect of the problem. With the available conditions, we obtained clear-screen brightnesses up to 60 ft-L, or an average-picture brightness of 6 ft-L. The preferred clear-screen brightness was discussed by the five observers and by others who viewed the test conditions, but did not participate in the test. They all preferred the higher screen brightnesses—something closer to 25 ft-L. I personally liked the 60 f-tL clear-screen brightness.

Dr. Lozier: In a theater with borders and surrounds covering as great a solid angle as you used, and with the high brightness you used, would there not be reflected in the audience area considerable light which would allow distraction?

Mr. Guth: The stray light from very high surround and border brightness may provide objectionable brightnesses in the audience area. This illustrates some of the practical problems that must be solved by studies in actual theaters.

O. E. Miller: I'd like to ask Mr. Guth if, in his experiments, he noticed any tendency to change the type of illusion that was created from the type that you get with no illuminated border around the screen? The reason I ask this is because I was involved in a few experiments some years ago with illuminated borders and have done some work in print illumination and transparency illumination, which seem to show that with an illuminated border the mode of appearance of the picture actually changes from that of a real scene to make it appear as if you were looking at a print. In other words, the actual mode of appearance changes.

Mr. Guth: That is correct if the border brightness is too high. The appearance of the picture and the created illusion were among the criteria used by the observers. They felt that if the border brightness was too high it affected the appearance of the picture. Even though there was no stray light upon the projected picture, the high border brightness did destroy the intended illusion. If they held the border brightness below a certain point, it had no noticeable effect. Of course, when one goes from a complete blackout to some brightness, an immediate change is obtained. However, over quite a range of brightnesses, there didn't seem to be too much effect upon the picture.

Photometric Factors in the Design of Motion Picture Auditoriums

By HENRY L. LOGAN

The photometric factors in designing the visual environment in a motion picture theater to promote the comfort, enjoyment and safety of the audience are discussed. The dependency relationship of screen surround and house brightnesses to screen brightnesses is explained. Optimum relationships are given and suggestions made for the practical execution of the recommendations, including the locations of lighting units and the shaping of the auditorium walls and ceilings.

THE PHOTOMETRIC factors of importance in the motion picture theater are the screen brightnesses with film running and their relationships with all the other brightnesses in the field of view that are necessary to promote the visual comfort, enjoyment and safety of the audience; and the brightness relationships without film running and full house lighting.

As all the difficulties arise with the former and not with the latter, this paper will be confined to the situation that exists with film running.

It will be found that a brightness distribution that accomplishes the goals just mentioned requires special handling of the screen and its adjacent surround, some modifications in the shape of auditoriums, predetermination of the percentage of light reflected from each part of the auditorium interior (and hence, determination of finishes) and precise control of the light emitted from the lighting equipment.

Up till now, the writer has had the impression that most motion picture theaters have been designed for their effect on the observer with full house lights on rather than for their effect when film is running.

With film running, motion picture screens average from 1 to 3 ft-L brightness. If we set the brightness relationships to meet the upper figure, we reduce the sensitivity of the eye to the darker portions of the film, even if we so light the theater that no house light can get back to the screen to reduce its contrasts. With auditoriums as they now exist, an overlay of diffused light on the screen is inevitable, which is one reason why house lighting is so little used when film is running.

Actually we are driven to take the least brightness that occurs on a black-and-white film as our starting point. This is about 0.04 ft-L and is the same brightness that Spragg has shown to be the minimum for satisfactory visual performance and safety.

Presented on May 2, 1951, at the Society's Convention Screen Viewing Factors Symposium, at New York, by Henry L. Logan, Holophane Company, Inc. (Illumination Service), 342 Madison Ave., New York 17, N.Y.

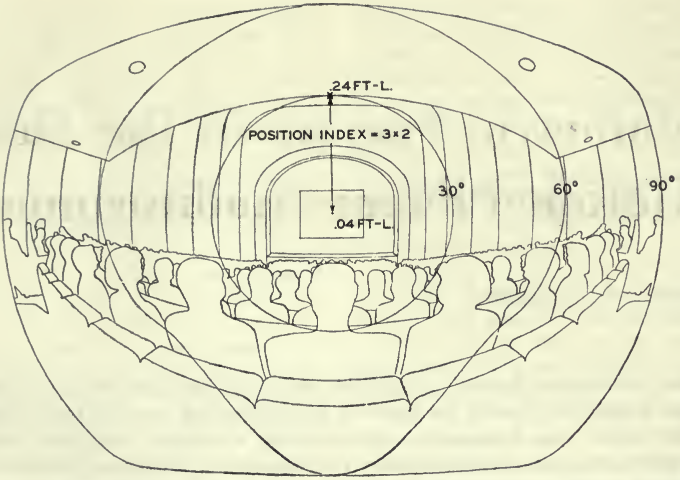


Fig. 1. Field of view of a patron seated in the standard observer's position, showing how the surround brightness 30° above the line of sight can be as much as six times the screen brightness by virtue of the position index relations.

Brightnesses located off the axis of vision have a lower-discomfort effect than similar on-the-axis brightnesses, as shown by the position-index data of Luckiesh and Guth,[1] and Harrison.[1a] Thus, the brightness of the surround adjacent to the screen can be greater than 0.04 ft-L without impairing the keenness of vision directed at the screen, and without introducing distraction.

For example, at a point 30° above the center of the screen the position index is 3, and if the line of sight is directed at the center of the screen, which has a night-scene running of 0.04 ft-L, the point 30° above the screen can have a brightness of 3 × 0.04 ft-L, or 0.12 ft-L, in order to produce a response equal to that caused by 0.04 ft-L screen brightness, provided the areas occupied are about equal (see Fig. 1).

The latest work of Guth (see the preceding paper in this Journal) shows that acceptable off-axis brightnesses can be twice as great when the observer is engaged in purposeful seeing, than when he is looking at random. As there is no doubt that an observer looking at running film has his attention deeply engaged, the surround brightness at this point, 30° above the axis, can safely be 2 × 0.12, or about 0.25 ft-L. This should permit both keen vision and a high degree of visual comfort under the condition of minimum screen brightness common today.

Thus, the brightness of the screen surround can begin with 0.04 ft-L at the screen edge and increase gradually, in accord with the position indices for critical seeing, as we proceed away from the screen along walls and ceiling.

The areas occupied by the brightnesses are important and in practice the position indices, when used to guide permissible surround brightness, must be changed by a factor to compensate for differences in area of screen and the strips of surround brightness.

This is quite consistent with the writer's earlier findings,[2] which gave a level of 0.1 ft-L as the permissible maximum brightness within 30° of the observers' line of sight.

Earlier in this discussion it was stated that we are driven to take the least brightness, that occurs long enough to measure on a black-and-white sequence,

as our starting point. This is because the next logical criterion would be the overall average brightness of the darkest running film, or 1 ft-L, and it would lead us into detrimental surround brightnesses.

Theoretically it would permit a screen surround brightness of 6 ft-L (3 × 1 × 2) at the previously mentioned 30° point. Against that we have the definite finding of Jones[3] that a brightness of 3 ft-L is the highest that can be tolerated toward the front of an auditorium.

Recent research[4] shows that visual comfort for 100% of the audience is about $\frac{1}{3}$ of tolerance (meaning by tolerance, the comfort–discomfort threshold). Therefore, the maximum *comfortable* screen surround brightness would be 1 ft-L or only $\frac{1}{6}$ of the figure we arrive at by using the overall average brightness of the darkest running film. It is safest, therefore, to stick to the criterion previously discussed, namely, the lowest brightness that occurs long enough to measure in a black-and-white sequence.

Coming to the rest of the auditorium, recent work by Guth,[5] Petherbridge and Hopkinson[6] (and its development by the writer) shows that higher brightnesses are desirable in other parts of the auditorium than was previously thought.

Before proceeding to a discussion of these brightnesses, it might be well to point out that acceptable screen surround brightnesses can be secured by utilizing the reflected light from the screen, in the fashion developed by Schlanger. The method consists of framing the screen in a recess of sloping reveals that are bathed in light from the screen. These reveals start at the edges of the screen, from which the black frame margin is absent, and slope outward toward the remainder of the auditorium. Schlanger has carried this idea even farther, and has sloped all his auditorium surfaces so they favorably receive light from the screen and reflect it into the house. This has the effect of maintaining the adaptation level of the eyes

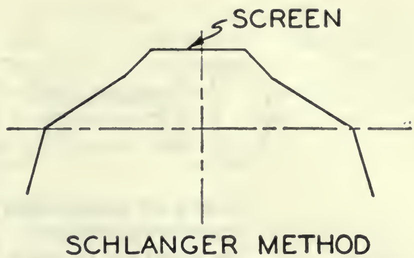


Fig. 2. Plan view of the proscenium and auditorium showing the relation between reveals and screen recommended by Schlanger.

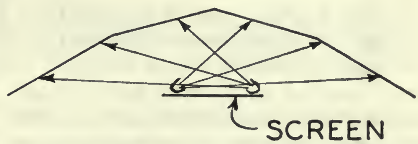


Fig. 3. Plan view of proposed reveal lighting arrangement, with light sources behind screen.

fairly close to that established by the screen, so that it is possible for a member of the audience to look all around such an auditorium, with the film running, and see comfortably well. Of course, high light-reflection factors are necessary, which restricts the range of decoration that can be used and gives the interior a somewhat severe aspect when house lights are on and film not running. Nevertheless, these interiors do give one the feeling that one is in an auditorium successfully designed for the showing of motion pictures to full advantage, and they impart a feeling of security to the observer that is lacking in most motion picture theaters.

The screen surround can also be properly lighted if the screen is set forward of similar reveals. The reveals, then, are lighted independently from sources behind the screen, either synchronously, varying along with screen brightness, or at a fixed level. For the fixed case, the reveals remain at the same brightness, independent of the fluctu-

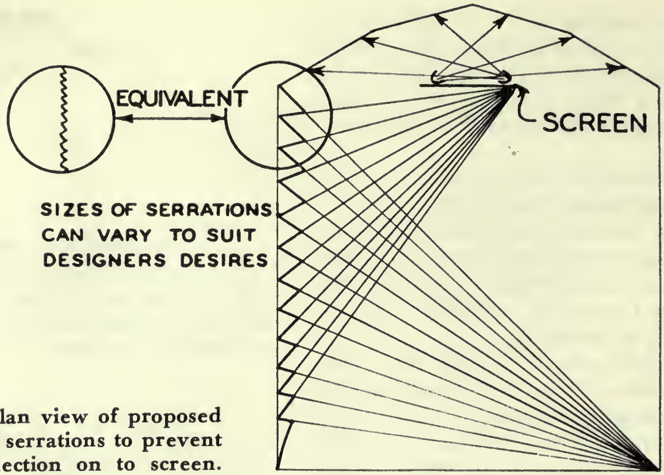


Fig. 4. Plan view of proposed system of serrations to prevent light reflection on to screen.

ations of screen brightness, and so must be keyed to darkest screen conditions, as explained. However, to prevent an overlay of light from the reveals onto the screen, the screen should be level with the front edges of the reveals, instead of, as in Schlanger's use of reveals, level with their back edges.

Returning to the subject of brightnesses in other parts of the auditorium, the sides of the auditorium at the proscenium end can start with a brightness of 0.25 ft-L, or, if the position indices do not permit, a lower value increasing to 0.25 ft-L which should be continued for about two-thirds the length of the auditorium. The walls of the back one-third can safely have a brightness of 0.5 ft-L.

The ceiling brightness should follow in the same way; 0.25 ft-L from the proscenium arch back for two-thirds of the ceiling, rising to 0.50 ft-L at the rear.

Brightness on the floor should be confined to the traffic aisles and the crossovers. Where aisle lights can be properly located and shielded from the eyes of the patrons, they provide a satisfactory solution. Another solution is downlights located and designed so as to light the aisles and crossovers only, and not spill light onto the audience. Floor brightnesses can start at 0.25 ft-L at front of auditorium, gradually rising to 1 ft-L on the rear crossover.

However, brightnesses at these levels will put a sufficient overlay of diffused light on the screen to interfere seriously with its clarity, unless the light is prevented from getting back to the screen.

One way to prevent it is to serrate the walls and ceilings; one face of each serration should be turned toward the audience and have a high light-reflection factor; the other face of each serration should be turned toward the screen and given a reflection factor of about 20%. These serrations can have various shapes, but a simple dogtooth section will work well.

In a rectangular auditorium both faces of the serrations would tend to be smaller toward the screen end, with the side facing the audience, larger toward the rear; while in an auditorium where the walls sloped in to meet the proscenium, the side of the serrations that faced the audience would be larger near the proscenium.

Various rhythms of size and shapes of the serrations are possible, depending upon the creative ability of the designer and the limitations in shape of the auditorium in question.

By using an absorbing finish on the faces of the serrations that face the screen, and reflecting finishes on the opposite faces, the walls can be lighted directly from the ceiling by lighting equipment running along and close to the walls. This equipment can be concealed by a variety of methods.

The ceiling will receive sufficient light by diffusion from the walls, but to have satisfactory brightness the reflecting faces of the ceiling serrations should be given a higher reflection factor than the reflecting faces of the wall serrations. However, they can be given a lower reflection factor if they are lighted independently from the walls. One way of doing this would be to make a horizontal break in the walls, say one-third down, providing a concealing ledge within which lighting equipment of the proper size and performance characteristics could be placed to light the ceiling indirectly. Such equipment would have to have perfect control as spill light on the walls should be avoided.

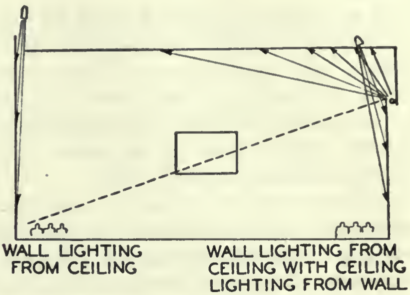


Fig. 5. Wall and ceiling lighting methods for desired surround illumination.

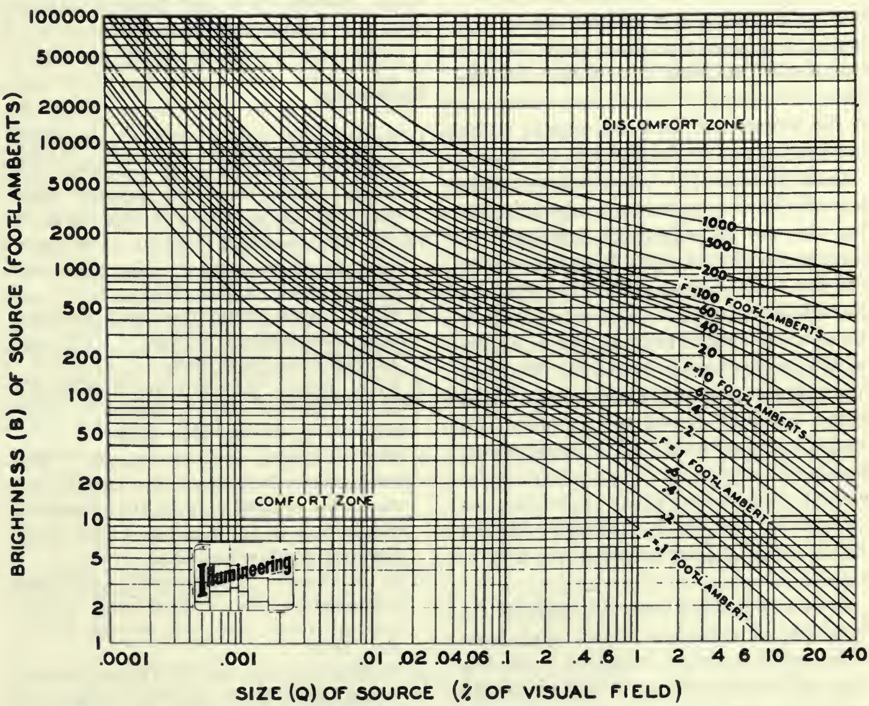


Fig. 6. Visual Comfort Chart—The comfort–discomfort threshold relations in terms of light source brightness, size and adaptation brightness. (Copyright 1951 Holophane Company, Inc.)

Finally, both the balcony face and the rear auditorium wall should be given the same reflection factor as the dark sides of the serrations, so that these surfaces, which face the screen, will not diffuse significant quantities of light to the screen.

If an observer placed himself at the screen in an auditorium designed in this fashion, and looked into the house, he would see only the dark sides of the serrations, and, with the exception of the lighted strips of floor in the aisles, the auditorium would appear dark.

On the other hand, if he went into the auditorium and faced the screen, he would see a well-lighted interior having a brightness distribution that gave him the same response as the darker sequences of the pictures. As he looked away from the screen, the auditorium would appear still brighter, and he would find it easy to look away from the picture and back again, in much the same way as you find it easy to look out of your living-room window onto your lawn and back to the interior of the room again, when daylight is coming through the window.

In both cases, the brightness distribution and level is such that visual adaptation is not significantly changed in moving the line of sight from the screen into the auditorium, or from the window into the living room. The sensitivity to the pictures would remain just as unimpaired as does your sensitivity to what you can see through the window, when sitting in your living room under the conditions described. The equipment, shapes of surfaces and finishes have to be worked out with great precision to accomplish the desired effects, as the effects occur only if *control of the light is complete.*

Colors of finishes must be selected on the basis of reflection factor and neutrality of observers' response. In the light of MacAdam's work (see his paper earlier in this Journal), care must be taken that the colors selected for the immediate screen surround do not distort the reception of Technicolor and Kodachrome in the eye. The aim is to provide a neutral surround to subordinate all elements in the theater to the projected image.

The entire screen surround and theater interior should be designed with modern illuminating engineering techniques and data borne in mind. Lighting proposals for theater interiors can be analyzed and carefully checked by the flux analysis method and evaluated with newly-developed visual-comfort criteria (shown in Fig. 6), to insure that the proposed interior will be found visually comfortable by 100% of an audience. In short, a complete design technique is now available that will permit experiments to be investigated on paper, with the outcome of the various proposals rather definitely determined at the paper stage, instead of at the client's expense after the theater is finished.

References

1. M. Luckiesh and S. K. Guth, "Brightnesses in visual field at borderline between comfort and discomfort," *Illum. Eng.*, vol. 44, pp. 650–670, Nov. 1949.

1a. W. Harrison and P. Meaker, "Further data on glare ratings," *Illum. Eng.*, vol. 42, pp. 153–179, Feb. 1947.

2. H. L. Logan, "Brightness and illumination requirements," *Jour. SMPE*, vol. 51, pp. 1–12, July 1948.

3. L. A. Jones, "The interior illumination of the motion picture theatre," *Trans. SMPE*, pp. 83–96, May 1920.

4. H. L. Logan and A. Lange, "The evaluation of visual comfort data," prepared for presentation at 1951 National Conference of Illuminating Engineering Society, Washington, D.C.

5. S. K. Guth, "Comfortable brightness relationships for critical and casual seeing," *Illum. Eng.*, vol. 46, pp. 65–75, Feb. 1951.

6. P. Petherbridge and R. G. Hopkinson, "Discomfort glare and the lighting of buildings," *Trans. Illum. Eng. Soc.* (*London*), vol. XV, No. 2, pp. 39–79, 1950.

New Approaches Developed by Relating Film Production Techniques to Theater Exhibition

By BENJAMIN SCHLANGER and WILLIAM A. HOFFBERG

A larger screen, camera angles, factors of psychophysical vision and auditorium viewing are considered relative to the development of more flexible screen cinematography. Screen masking, surround and auditorium environment are also considered.

It is gratifying to report at this time the increasing recognition of the significance of auditorium and screen environment in relation to greater film enjoyment. There is also now a more ready acceptance of larger screens. These developments are due to the increased use of color film and the competition of television. The disadvantages of a dark auditorium and screen environment have become apparent due to the recognition of the resulting visual fatigue and the essential unpleasantness of blackness; color film accentuates this. The Symposium on Screen Viewing Factors, to which this paper is a contribution, concerns itself with the above scope and is in itself evidence of a trend.

Since our last paper presented to this Society in October 1950,[1] we have made further studies which now enable us to make some definite recommendations for a dramatic improvement in motion picture exhibition in theaters. We now propose a substantial increase in the size of theater screens together with a new use of the increased areas beyond present picture sizes. The added screen area should be devoted to peripheral and interpretive cinematography as well as occasional use of the entire screen area for clearly defined images. This proposed exploitation of the additional screen area is of intrinsic importance.

The advocacy and use of large screens has a long history. However, within the last 20 years, improvements in film grain reduction, studio set lighting and the increase of projection light intensity have now made the large screen feasible. Certainly the novelty factor of sound which was introduced about 1927, when large screen trials were made, has now been dissipated. A major fault of the early large screen attempts was the absence of a cinematography consistent with wide-angle viewing in theaters. As a result, the audience experienced the annoyance of moving their eyes to follow the extreme positions of action and the

---

Presented on May 2, 1951, at the Society's Convention Screen Viewing Factors Symposium, at New York, by Benjamin Schlanger and William A. Hoffberg, Theater Engineering and Architecture Consultants, 35 W. 53d St., New York 19.

Figure 1

constant doubt as to whether they were looking at the center of concentration.

In our opinion, the effective use of the large screen is made possible by the following suggested production and exhibition techniques:

Flexible Cinematography

By using the larger screen as a palette, a more flexible cinematography is made possible. The present aspect ratio (width: height) of 8.25:6.0 is a straight-jacket for the cinematographer since various scenes require varying aspect ratios. By the use of darker vignettes, the cinematographer at present can vary his shape but he must sacrifice valuable screen area, as observed by Lewis W. Physioc in 1931, who wrote: "Vignetting and other effects are prohibited by the limited areas."[2] The use of light vignettes is comparatively rare because existing screen surround treatments are invariably dark.

|←——New Screen——→|

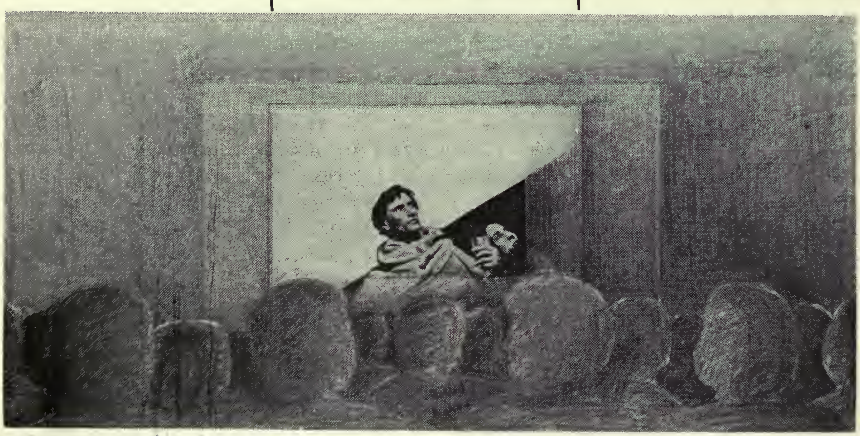


Figure 2

Figure 1 depicts a present screen in the usual dark theater as viewed from a distance of about 90 ft from the screen, which is 5 times the screen width of 18 ft. Figure 2 is taken from the same viewing distance of 90 ft and shows the effect with a 30-ft screen; the viewing distance is thus 3 times the screen width. The size of the head in the picture is the same in both illustrations but Fig. 2 illustrates a light vignette extending into a light screen surround and a dark vignette extending into a dark screen surround. As a result, there is no apparent aspect ratio or confining frame. The effects shown in Fig. 2 have heretofore been impossible to achieve.

Synchronous, Luminous Peripheral Extensions

The larger screen would be used for clearly defined picture content and vignetted as well as peripheral extensional surrounds. All of the desired effects would be on the 35-mm film. The cameraman will have designated on his view-finder the boundaries of clearly defined detail area. This area will vary in size and shape to suit the requirements of the scene. The props, background and people located in the portions beyond the clearly defined area will be recorded on the film only to establish light intensity and color, thus forming an atmospheric extension of the detailed picture.

By the use of diminished lighting or increased lighting in the periphery, for interior shots, the outer areas are recorded as vignettes which diffuse to light as well as dark terminations. For certain interior shots and most exterior shots, it will be more appropriate to use diffusing tonal extensions which will be obtained by placing in the camera or in the optical printer a filter which has an open area equivalent to the defined picture area. The above filter is placed at a distance from the sensitized film so as to establish an amount of diffusion which will create color and light intensity extension with or without identifiable detail. The vignettes and peripheral extensions would always automatically *synchronize* with the detailed portion of the picture.

Picture Shape

In 1929, L. A. Jones[3] made some very pertinent observations regarding various aspect ratios. He came to the conclusion that it is impossible to get a standard proportion which will satisfy the variety of forms of compositional construction. He found that for landscape and mass compositions the most favorable ratio of width: height ranged from 1.55 to 1.60 but for portrait compositions this ratio varied from 0.88 to 1.48. This indicates the great difficulty in fixing a constant aspect ratio in cinematography. Flexibility of shape offers a solution. Not only should there exist the ability to vary the proportions of the rectangle but there should also be the possibility of using any other shape. It is also significant that it is possible to dissolve the sense of shape by the use of luminous as well as darkened vignettes and thus achieve a "shapeless shape."

Use of Wide Angle Lenses

There has been a marked trend since 1939 toward the increased use of wide-angle lenses in film production. Prior to this date, the use of a 25-mm lens with a camera angle of 47.5° was exceptional. In 1928, A. C. Hardy and R. W. Conant[4] stated that to avoid perspective distortions in theater viewing, the correct location is obtained by multiplying the projection distance in the theater by the ratio of the focal length of the camera lens to the focal length of the projection lens. With a camera lens of 2-in. focal length and projection lens of 4-in. focal length, as determined by present screen size, the best viewing position would therefore be at a distance from the screen equal to one-half the distance from the projector to the screen. With a 1-in. camera lens and 4-in. projector lens,

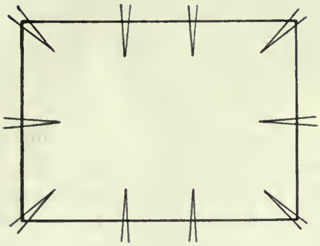


Figure 3

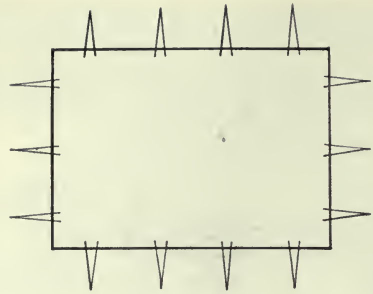


Figure 4

the best viewing position would be at one-fourth the distance from projector to screen. The increased use of wide-angle lenses therefore has a detrimental effect on the best viewing position in the theater since it throws this point too far forward, namely about in the third row orchestra.

With the recommended use of the larger screen, the focal length of the projection lens would be reduced to about 2.5 in. and with a 1-in. camera lens, the best viewing position would be at two-fifths of projector to screen distance or about the tenth row orchestra. The change to larger screens is consistent with the already increased use of wide-angle camera lenses.

Occasional Use of Full Screen

Although we propose that the detailed picture area will occupy varying amounts of the total screen area for the major portion of the time, it is possible and advisable for climactic, tonic and panoramic scenes to use a maximum of the entire screen surface. This occasional use of the entire screen, which is all produced on the film, does not require the expensive and cumbersome mechanical spreading devices for the screen masking.

Effective Use of Screen Area

It is important to observe that in present cinematographic practice there is a tendency to "play safe" by avoiding the use of the marginal areas of the screen. Figure 3 is intended to express the diagrammatic force of pictorial composition as influenced by the usual black masking and dark screen surround. By way of contrast, in Fig. 4 is the expression of the relative effect of an outward force which becomes possible with the synchronized extension in light, shade and hue as previously described. The ability to extend important detail and effects up to the extreme edges of the detailed picture increases the effective area of the picture.

Visual Experience in the Peripheral Zone

Psychological as well as physiological factors must be evaluated in order to analyze visual experience. Little consideration has been given heretofore to the problem of expressing the effects which occur in the peripheral zone. Figure 5 represents the portion of the field of view occupied by the camera angle of a wide-angle lens of 1-in. focal length. This angle of 47.5° includes varying angles of peripheral experience. Figure 6 indicates the portion of the field of view of the spectator in the theater from the furthest and closest seats, as expressed by the ratio of viewing distance to width of picture and shown as $5W$ and $1W$. The proportion of the field of view occupied by the screen from the average viewing position is far less than the widest camera angle and occupies much too small a segment of the total field of view.

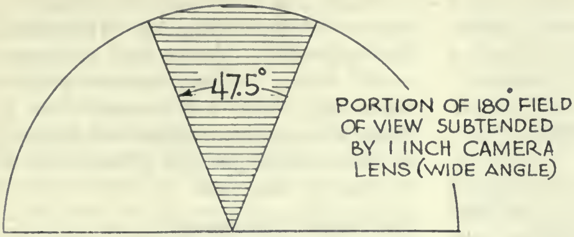


Figure 5

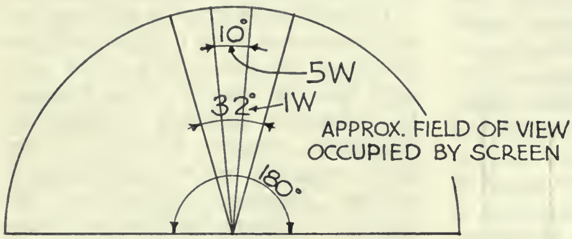


Fig. 6. Field of view in existing theaters.

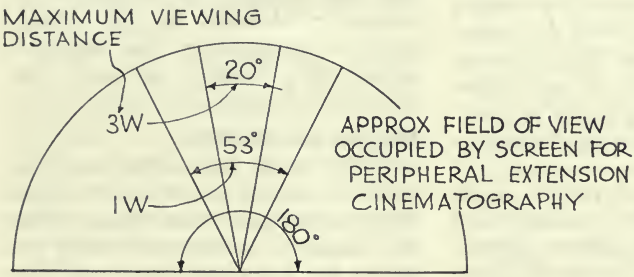


Fig. 7. Field of view as recommended.

Figure 7 indicates the proposed increase in screen size and its effects on the proportion of the spectator's field of view as seen from $3W$ and $1W$. It becomes evident that, with the increasing use of wider angle camera lenses up to 1-in. focal length, the screen in the theater should subtend an angle consistent with camera angles. A synchronized luminous field surrounding the projected picture, as hereinafter described, subtends a still greater angle into the peripheral zone.

Concentration and Diffusion in the Field of View

It is most significant that the portion of the field of view of the human eye, which appears less distinct and almost obscured, varies considerably with the amount of concentration experienced at any given moment. The angle of clear vision detail discernment *narrows* as the degree of concentration increases. In direct contrast with this, when there is least reason for concentration, as in a panoramic view, we seem to see a maximum of the total field in more or less clearly defined detail. The viewer is hardly aware of the slight movements of the eye muscles which enable him to encompass the panorama clearly.

As concentration increases in intensity, the angle of clear vision decreases and the degree of *diffusion* of detail outside of this zone increases. These observations offer the clues as to how best to interpret cinematographically these experiences and help to determine the types of vignettes and filters to be employed. For example, in an interior shot where intense concentration occurs,

the vignetting process will diffuse detail at a point close to the main interest and extend therefrom into areas of light or shadow as the scene dictates.

Synchronous, Luminous Screen Surround

Even the recommended enlarged screen does not occupy a sufficient portion of the spectator's field of view in the theater. The subtended angles to the screen at viewing distances of $1W$, $2W$ and $3W$ are respectively 53°, 28° and 19°. It is therefore highly desirable to extend the sensation of luminosity beyond the screen area so that the resultant subtended angle of the total luminous field consisting of screen and screen surround approaches the subtended angle of a 1-in. camera lens. We have found that this screen surround luminosity must be synchronous with the light intensity of each scene and, with color, the hue of this surround must be an extension of the colors in a scene.

The screen surround begins at the edge of the projected picture and extends to the audience at an angle of approximately 45° to the plane of the screen. It has a slight concave curvature toward the audience in order to control gradations of light shading which are synchronous reflections of the projected picture. The surface of the surround usually consists of a diffusive finish. The dimensions of the screen surround will vary with the size of the picture and the size and shape of the auditorium, similar to installations recently made by us in the Crown Theatre, New Haven, Conn., and the Shopping Center Theatre, Framingham, Mass.

It is, of course, mandatory to provide a proper transition between the projected screen image and the luminous surround because of the fuzziness, color aberration and image movement discernible at the edges. We have solved this problem by the use of a translucent plastic material located so as to overlap the edges and to reveal a comparatively narrow luminous framing. This framing successfully blends the aforementioned defects into the luminous picture surround. Thus the necessity for a black masking is completely eliminated; its use would negate the effectiveness of the picture surround.

Auditorium Environment

The proposed screen size and luminous screen surround do not occupy a sufficient portion of the field of view of the spectator from the rear of the auditorium. It is therefore necessary to make the auditorium surfaces adjacent to the screen surround act as a transition to relative darkness. Fortunately, the tendency in theater architectural design has been toward the elimination of distracting elements on the surfaces visible to the audience, thus helping to achieve the necessary neutrality, simplicity and destruction of scale.

Purpose and Feasibility

1. It is highly improbable that home television viewing will be able to present the dramatic scale and impact which this suggested development makes possible. An important step would thus be achieved toward re-establishing the motion picture theater as a unique medium of entertainment.

2. This development provides new tools and techniques which help remove some of the shackles which have long hampered the cinematographer.

3. It provides an atmospheric extension of picture light, shade and color which is more closely related to visual experience. Certainly, the removal of the black surround for color pictures is much to be desired.

4. It is generally conceded that the reduction of contrast between picture-light intensity and surround-light intensity will reduce visual fatigue and we further contend that synchronization of the surround and picture lighting will more successfully reduce this contrast.

5. The ability to place important action in remote positions of the enlarged screen is consistent with the objectives of stereophonic sound.

6. Most existing theaters can accommodate the enlarged screen. The sight-line clearances in some theaters will not include the full height of the screen from some of the seats but this will not be serious because the obstructed areas of the enlarged screen will usually be within the zones of atmospheric extension. The enlarged screen would be placed as low as possible with the intent of destroying the rigid horizontal line at the bottom of the picture. Existing seating patterns and distance to the first row of seating would not have to be changed since the entire enlarged screen is used for sharply defined images only occasionally.

7. The cost of adapting existing theaters to this system is limited to providing a new screen and the surround treatment, new projection lenses and, in some instances, new projection lamp-houses and wiring provisions. The only additional operating cost is the increased current consumption.

8. This development does not require any radical change in production equipment. The minor modifications necessary to effect the vignetting and diffusing characteristics herein proposed should not be costly.

9. Although this development lends itself admirably to any increase in film width, it is feasible with the use of 35-mm film since the image enlargement which is required is similar to many large screens now in use.

10. For new film productions using the above techniques, it is an important feature that separate prints can be made which are adapted for use on existing screens by printing only the clearly defined image for the entire film width and omitting the peripheral extensions. It is also possible to reprint existing films by the use of filters in the optical printer to simulate the desired effects.

The early feasibility of this proposal was accented in all of the above research and development.

References

1. B. Schlanger and W. A. Hoffberg, "Effects of television on the motion picture theater," *Jour. SMPTE*, vol. 56, pp. 39–43, Jan. 1951.
2. L. W. Physioc, "Problems of the cameraman," *Jour. SMPE*, vol. 17, pp. 406–416, Sept. 1931.
3. L. A. Jones, Bulletin No. 410 of the Kodak Scientific Research Laboratory, Rochester, N.Y., 1929.
4. A. C. Hardy and R. W. Conant, "Perspective considerations in taking and projecting motion pictures," *Trans. SMPE*, vol. 12, no. 33, pp. 117–125, 1928.
5. B. Schlanger, "Increasing the effectiveness of motion picture presentation," *Jour. SMPE*, vol. 50, pp. 367–373, Apr. 1948.
6. B. Schlanger, "On the relation between the shape of the projected picture, the areas of vision, and the cinematographic technic," *Jour. SMPE*, vol. 24, pp. 402–409, May 1935.

Report on Screen Brightness Committee Theater Survey

By W. W. LOZIER, Committee Chairman

A PRELIMINARY survey of 18 theaters by the Screen Brightness Committee in 1947[1] disclosed interesting indications of theater screen illumination practice in this country, but was inconclusive because the theaters covered represented too limited a sampling. A more extensive survey was not carried out at that time because of the lack of a suitable meter. More recently, the General Electric Company placed at the disposal of the Committee a meter which is better adapted to a theater survey. Consequently, during the summer of 1950, the Screen Brightness Committee of the Society undertook a survey of screen illumination and related factors in 100 representative indoor theaters. It was the Committee's purpose in this larger survey to cover a more representative segment of the theaters in this country and to obtain dependable data concerning their practices, with the underlying thought that observation and discussion of any undesirable conditions would promote better projection. At the present time, results are available on 125 theaters, representing all except the Southeast and Pacific sections of the United States. It is believed that these results would not be greatly changed by representative coverage of these additional areas.

During the course of this survey, the Motion Picture Research Council became interested in carrying out a parallel survey in the West Coast studio review rooms used for viewing 35-mm pictures. Through their cooperation, we are able to include in this report the results on 18 review rooms.

Methods and Instruments

In contrast with the previous survey, all of the measurements in the present survey were made with an objective-type instrument requiring no visual photometric balance. Nearly all of the measurements were made with the two-cell General Electric combination screen illumination–screen brightness meter. A few measurements were made employing a simple foot-candle meter in combination with an improvised device for measuring the screen reflectivity.[2]

Data forms were simplified somewhat from those used in the 1947 survey and are illustrated in Figs. 1 to 3.

Classes of Theaters Surveyed

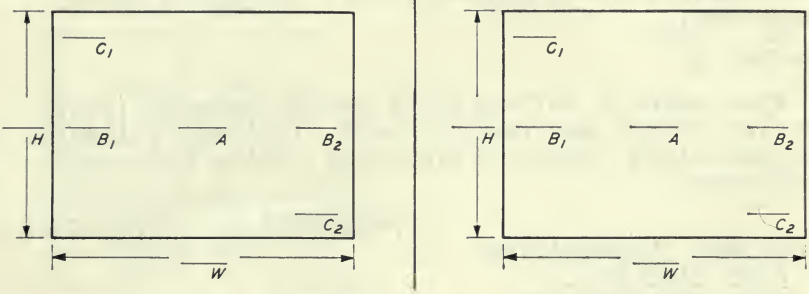
The 1947 survey was heavily weighted by the large downtown theaters in large cities. An effort was made in this survey

Presented on May 2, 1951, at the Society's Convention at New York, as a preliminary progress report on the first 88 theaters of this survey, by W. W. Lozier, Committee Chairman, Carbon Products Service Dept., National Carbon Company, Division of Union Carbide and Carbon Corp., Fostoria, Ohio.

SCREEN BRIGHTNESS COMMITTEE
THEATER SURVEY

THEATER ____________________ DATE ____________________
ADDRESS ____________________ REPORTED BY ____________________
____
____

PROJECTOR 1 | **PROJECTOR 2**



READ INTENSITY ON THE SCREEN IN FOOT-CANDLES AT THE FIVE POSITIONS INDICATED. "C_1" AND "C_2" ARE LOCATED $\frac{1}{20}$ OF H FROM EDGES AND $\frac{1}{20}$ OF W FROM SIDES. "B_1" AND "B_2" ARE ON THE HORIZONTAL CENTER AND $\frac{1}{20}$ OF W FROM SIDES. "A" IS IN THE EXACT CENTER.

Projector 1

SCREEN AREA

AREA IN SQUARE FEET = $H \times W$ = (1)

SCREEN LIGHT INTENSITY AND DISTRIBUTION

RATIO $\frac{B_1 + B_2}{2} \times \frac{1}{A} =$

RATIO $\frac{C_1 + C_2}{2} \times \frac{1}{A} =$

SCREEN LUMEN CALCULATION

$A \times 2 =$

$B_1 + B_2 =$

$\frac{C_1 + C_2}{2} =$

TOTAL =

WEIGHTED AVG. = $\frac{\text{TOTAL}}{5}$ = (2)

SCREEN LUMENS = (1) x (2) =

Projector 2

SCREEN AREA

AREA IN SQUARE FEET = $H \times W$ = (1)

SCREEN LIGHT INTENSITY AND DISTRIBUTION

RATIO $\frac{B_1 + B_2}{2} \times \frac{1}{A} =$

RATIO $\frac{C_1 + C_2}{2} \times \frac{1}{A} =$

SCREEN LUMEN CALCULATION

$A \times 2 =$

$B_1 + B_2 =$

$\frac{C_1 + C_2}{2} =$

TOTAL =

WEIGHTED AVG. = $\frac{\text{TOTAL}}{5}$ = (2)

SCREEN LUMENS = (1) x (2) =

Fig. 1. Sample data form for incident screen illumination.

to cover a wider range of types and sizes of indoor theaters. Figure 4 shows the distribution of seating capacities among the 125 theaters surveyed. It also shows the distribution of seating capacities among the indoor theaters of the United States expressed both on the basis of percentage of theaters in various seating ranges and also as the percentage of the total theater seating capacity falling in the different seating-capacity ranges. It is seen that the distribution of

SCREEN BRIGHTNESS SURVEY

CENTER SCREEN BRIGHTNESS AND REFLECTIVITY

(Incident Illumination) x (Screen Reflectivity) = (Screen Brightness)

Method A

When using a combination illumination and brightness meter, measure center of screen values of (Incident Illumination) and (Screen Brightness) and calculate (Screen Reflectivity) using the above equation.

Method B

When using a reflectivity meter, measure (Screen Reflectivity) and combine with (Incident Illumination) to calculate (Screen Brightness) using the above equation.

	PROJECTOR 1	PROJECTOR 2
INCIDENT ILLUMINATION FOOT CANDLES___	________	________
SCREEN REFLECTIVITY PER CENT___	________	________
SCREEN BRIGHTNESS FOOT LAMBERTS___	________	________

Fig. 2. Sample data form for screen reflectivity and screen brightness.

theaters covered in our survey corresponds more closely to the distribution of the total United States theater seating capacity than to the distribution of number of theaters among the various seating ranges. While the less-than-500-seat theaters account for over half of the total number of indoor theaters, they account for only a little more than one-quarter of the total number of seats.

Figure 5 gives the distribution of screen widths measured thus far. All but a small fraction of the screens were between 14 and 24 ft in width, with the average at approximately 18 to 20 ft.

Screen Brightness

The distributions of screen brightness encountered with 36 review-room projectors and 245 indoor-theater projectors are given in Fig. 6. The present ASA standard limits, also shown in Fig. 6, call for a brightness between 9 and 14 ft-L. The indoor theaters ranged in brightness from 3.4 to 53 ft-L, with approximately one-quarter below and about one-half within the ASA standard range. Two theaters which were equipped with highly directional "silver" screens had a central maximum screen brightness in the range of 30 to 53 ft-L. In the case of the review rooms, almost two-thirds were within the standard limits and most of the remaining third exceeded the maximum limit.

Distribution of Illumination Over Screen

Figure 7 shows the distribution of illumination over the screen expressed as a ratio of side-to-center intensity of incident illumination. Side distribution ranged from 40% to 94% for the indoor theaters with approximately 85% of the projectors falling between 50% and 80%

SCREEN BRIGHTNESS SURVEY

PROJECTION DATA

1.	PROJECTION ANGLE	____
2.	ARC LAMP TYPE	____
3.	POSITIVE CARBON	____
4.	NEGATIVE CARBON	____
5.	ARC AMPERES	____
6.	ARC VOLTS	____
7.	PROJECTION LENS	____
	(a) f/ NUMBER	____
	(b) FOCAL LENGTH	____
	(c) SURFACE COATED	YES __ NO
8.	TYPE OF SHUTTER	
	(a) DEGREE OPENING	____
9.	DRAFT GLASS TYPE	____
10.	HEAT FILTER TYPE	____
11.	PROJECTION PORT GLASS	YES __ NO
12.	TYPE OF POWER SUPPLY	____
	(a) RATING IN AMPERES	____
	(b) RATING IN VOLTS	____
	(c) OPERATING VOLTAGE	____

AUDITORIUM DATA

1.	SEATING CAPACITY	____

Fig. 3. Sample data form for theater data.

distribution ratios. The most frequent distribution ratio fell between 60% and 70%.

The review rooms differ radically from the indoor theaters by having a much more uniform distribution of illumination over the screen. Of the review-room projectors 85% produced a side distribution between 80% and 100%. This more uniform screen distribution reflects the review-room problem of small screen size and excess illumination; defocusing the light source to produce a uniform distribution is one way which has been used to reduce excess screen brightness. It means, however, that motion pictures are viewed in these review rooms under conditions very different from those prevaling in motion picture theaters.

Figure 8 gives similar information on the ratio of corner-to-center incident intensity. Corner distributions are, in each case, approximately 10% to 15% lower than the side distribution and ranged from 26% to 83%. Figure 8 shows, however, the same basic pattern as Fig. 7.

Screen Reflectivity

Less than half of the indoor theater screens had reflectivities in the 70% to 80% range, typical of a matte white screen in good condition. Over 40% of the screens ranged from 70% down to 32% reflectivity. Approximately 10% of the screens had reflectivities between 80% and 100%. Five "silver" screens were in the range of 150% to 250%. A total of eight "silver" screens are included in Fig. 9.

The review-room screens, on the aver-

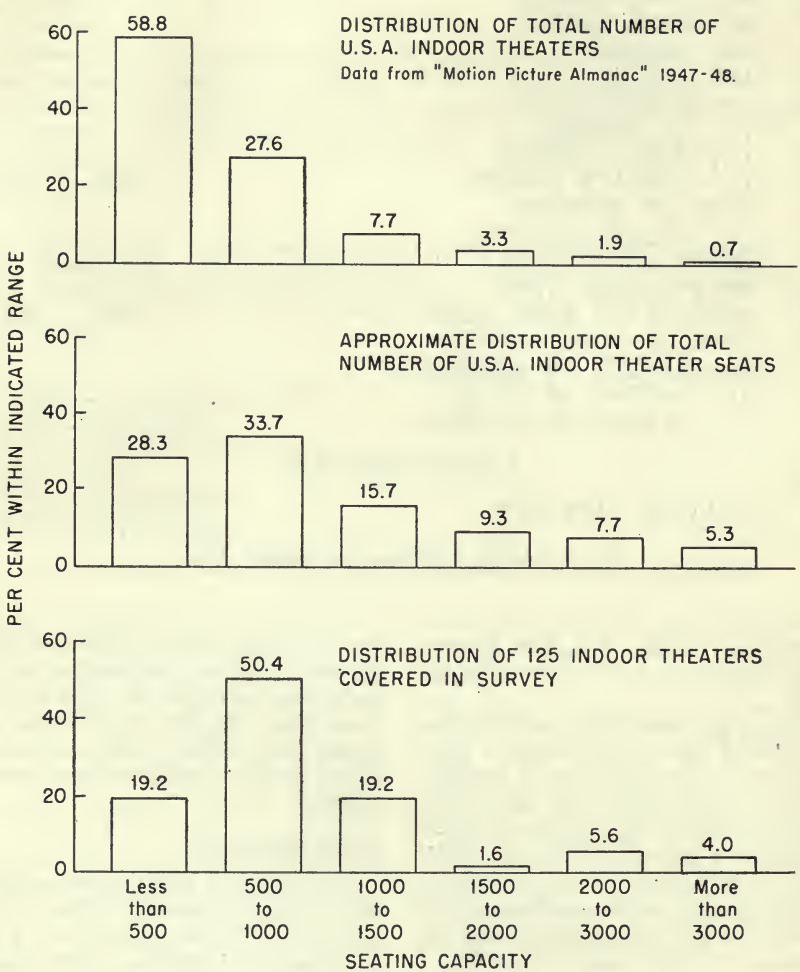


Fig. 4. Analysis of seating capacities of survey theaters and total United States indoor theaters.

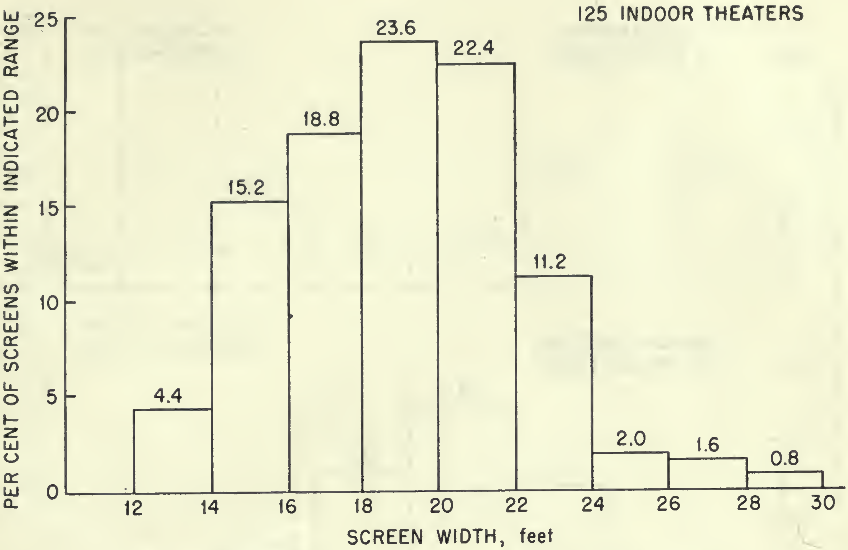


Fig. 5. Distribution of screen widths covered in the survey.

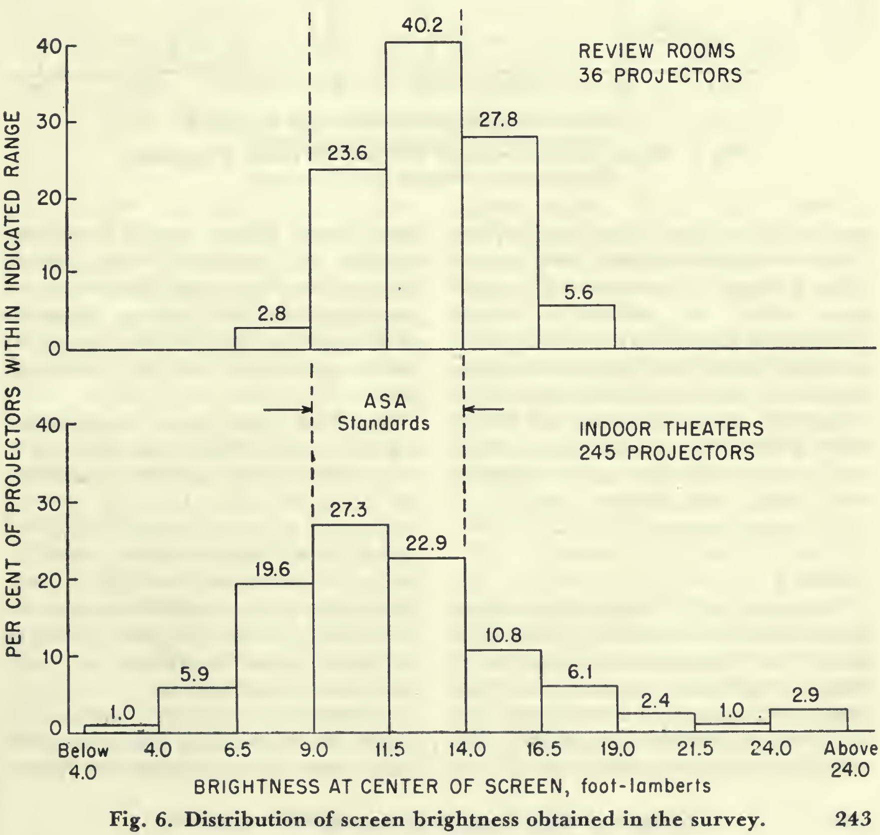


Fig. 6. Distribution of screen brightness obtained in the survey.

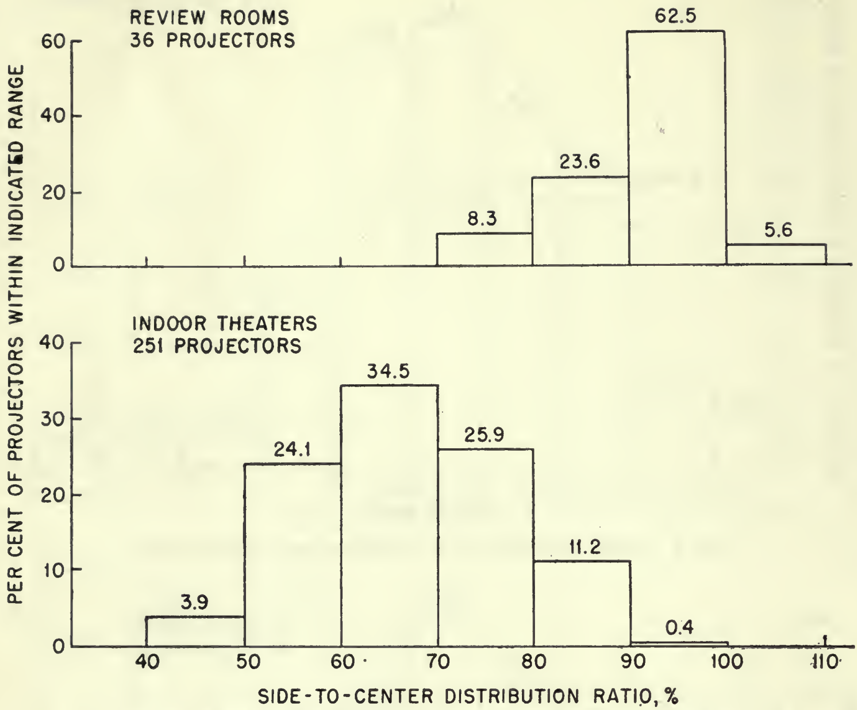


Fig. 7. Range of side-to-center distribution ratios of incident illumination obtained in the survey.

age, tended to have lower reflectivities than the indoor theaters, but not as great a range of extremes. This may again reflect the problem of excess illumination and the fact that even a deteriorated screen will produce adequate brightness with the small-size screens employed. However, if the low reflectivity is the result of deterioration, then such screens may also have undergone color change with resultant distortion of color motion pictures.

Summary

This survey of 125 indoor theaters has shown that the screen brightness falls within the recommended range for a little over half of the projectors, but that almost one-quarter of the theaters are below the recommended standards. The distribution of illumination over the indoor theater screens ranges from very uniform to extremely nonuniform. Screen reflectivity for the indoor theaters ranges from values typical of screens in good condition all the way down to values representing over 50% deterioration.

The West Coast review rooms generally show screen brightness within or a little above the recommended standards for indoor theaters. However, the review rooms differ from indoor theaters in having exceptionally uniform distribution of illumination over the screen. Review-room screen reflectivities show a lower average value than, but not nearly as great a spread of extreme values as, the indoor theater screens.

Compared to the 1947 preliminary survey, the present one shows an even wider range of screen brightness values,

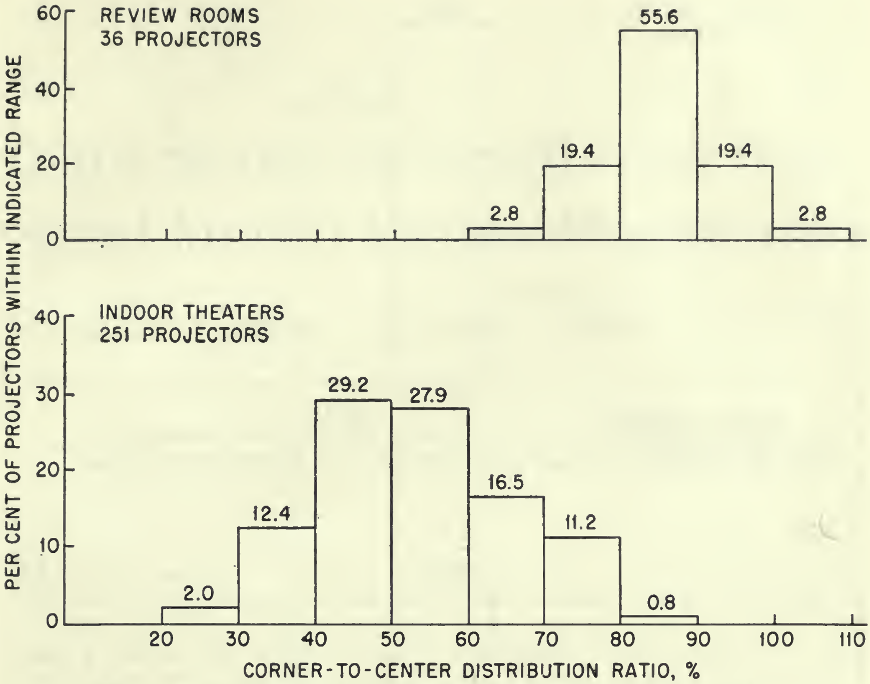


Fig. 8. Range of corner-to-center distribution ratios of incident illumination obtained in the survey.

but only about one-half as great a proportion of theaters below the recommended minimum brightness. Other factors studied, such as side and corner screen distribution ratio, cover approximately the same ranges as observed in the earlier survey. The screen reflectivities extend over a much wider range, including both some exceptionally low values and also a number of "silver" screens of extremely high reflectivity.

Recommendation

It is expected that the results of this survey will assist in the formulation of an eventual Committee recommendation for improvement of projection practice in theaters. In the meantime, however, it is believed that better attention to details of operation and maintenance can reduce the wide range of screen brightness observed and eliminate many of the extreme values. It can also eliminate many of the highly nonuniform distributions of illumination over the screen and thereby remove some of the objectionable conditions prevalent.

The findings of this survey in the West Coast review rooms are being considered by the Motion Picture Research Council and West Coast studios in relation to their program of improving review-room practices.

Acknowledgments

The Screen Brightness Committee and the Society are indebted to many people for assistance in the conduction of this survey. Theater projectionists, and their organization the IATSE, various trade publications and theater managers have been most cooperative in making their facilities and assistance available to us. Particular thanks are due to C. W.

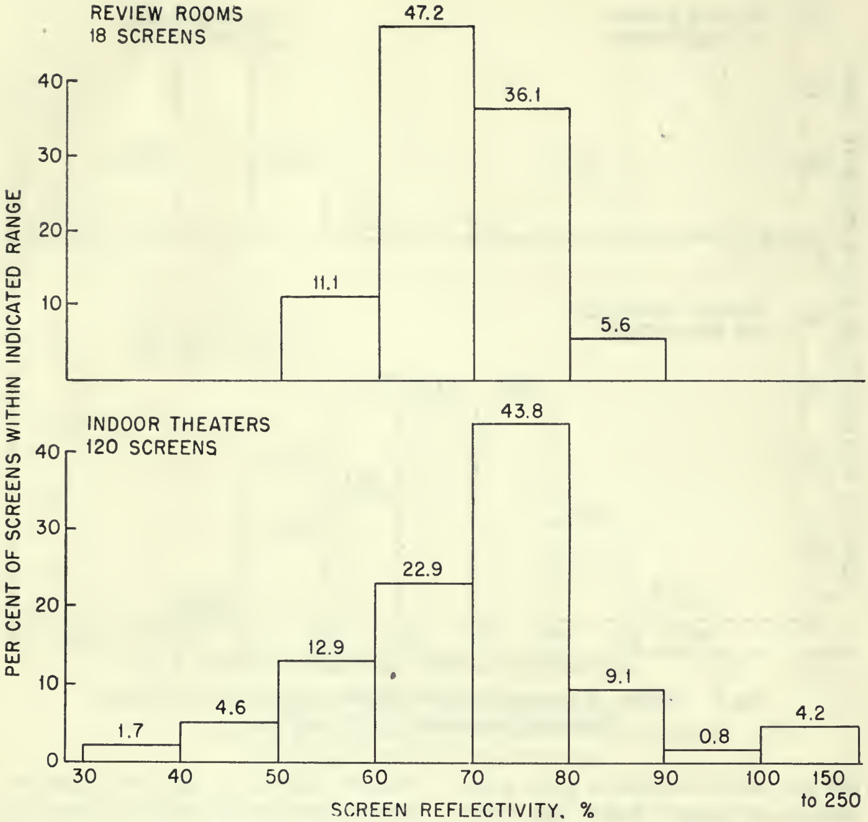


Fig. 9. Range of screen reflectivities obtained in the survey.

Handley, C. E. Heppberger and P. D. Ries of the National Carbon Company, A. J. Hatch of Strong Electric Corp. and C. R. Underhill of RCA for supervising and carrying out much of the survey work in the different areas of the United States. The Motion Picture Research Council took the initiative in obtaining the data on the West Coast review rooms. Without the fine cooperation of these individuals and groups, this survey would have been difficult if not impossible.

References

1. E. R. Geib, Chairman, "Report of Screen Brightness Committee," *Jour. SMPE*, vol. 50, pp. 260–273, Mar. 1948.
2. W. W. Lozier, Chairman, "Screen Brightness Committee Report," *Jour. SMPTE*, vol. 54, pp. 756–757, June 1950.

The Committee

W. W. Lozier, *Chairman*

Herbert Barnett	F. J. Kolb
H. J. Benham	W. F. Little
F. E. Carlson	L. J. Patton
M. H. Chamberlin	Leonard Satz
E. R. Geib	J. W. Servies
L. T. Goldsmith	B. A. Silard
L. D. Grignon	Allen Stimson
A. J. Hatch, Jr.	C. R. Underhill, Jr.
L. B. Isaac	H. E. White
W. F. Kelley	A. T. Williams
	D. L. Williams

Light Source for Small-Area High-Speed Motion Picture Photography

By RICHARD I. DERBY and ARTHUR B. NEEB

An illuminant which may be of interest to others working in this field has been assembled to give extremely high intensity for small-area use.

With the advent of the G.E. No. 750R-40 lamp designed for use primarily in high-speed motion picture photography, a large number of lighting problems have been greatly aided or solved.

In this laboratory, a lighting problem arose in which an area of about 2 to 3 sq in. was to be illuminated with such intensity as to obtain a field depth of about 2 in. at the minimum subject–lens distance. The light source to be described consists of one lamp and allows the use of Super X (not XX) film with a normal exposure index of 32 tungsten at *f*/10 using a 102-mm lens and a film speed of 3120 frames/sec, with a subject of medium reflectance (about 30%).

The source simply consists of one sealed-beam Par 64 No. 4560 G.E. lamp normally used as an airplane-wing light for illumination during night landing. The 28-v, 600-w lamp receives its power through a 20-amp variable transformer set at 30 to 33 v; this will no doubt decrease the lamp's normal life of 25 hr.

In conjunction with the lamp, a 6-in. planoconvex condenser lens, borrowed from an Omega type DII enlarger, was used. With the transformer set at some low voltage, the lamp was set up at about 3 to 4 ft from the subject while the condenser was aligned at 6 to 10 in. from the subject according to the desired dimension of the spot and its intensity. Full voltage was applied only during actual exposure.

The lamp was mounted easily in a short metal tube of the proper diameter, with a narrow flange rolled in on one end, against which the lamp is held by a Bakelite strip. The strip was fitted across the open end of the tube and attached by means of spring clips and pins. A mounting bracket spot-welded to the tube allows the assembly to be placed on a standard lamp stand. The condenser lens used with the lamp is fastened in a tube with a split retainer ring holding the glass against a flange rolled into the end of the tube.

A mounting bracket is fastened to the assembly so that it can also be used on a stand.

One must naturally take into consideration the great amount of energy in the form of heat which will impinge on

A contribution submitted July 11, 1951, by Richard I. Derby and Arthur B. Neeb, Research Dept., General Mills, Inc., 2010 E. Hennepin Ave., Minneapolis 13, Minn.

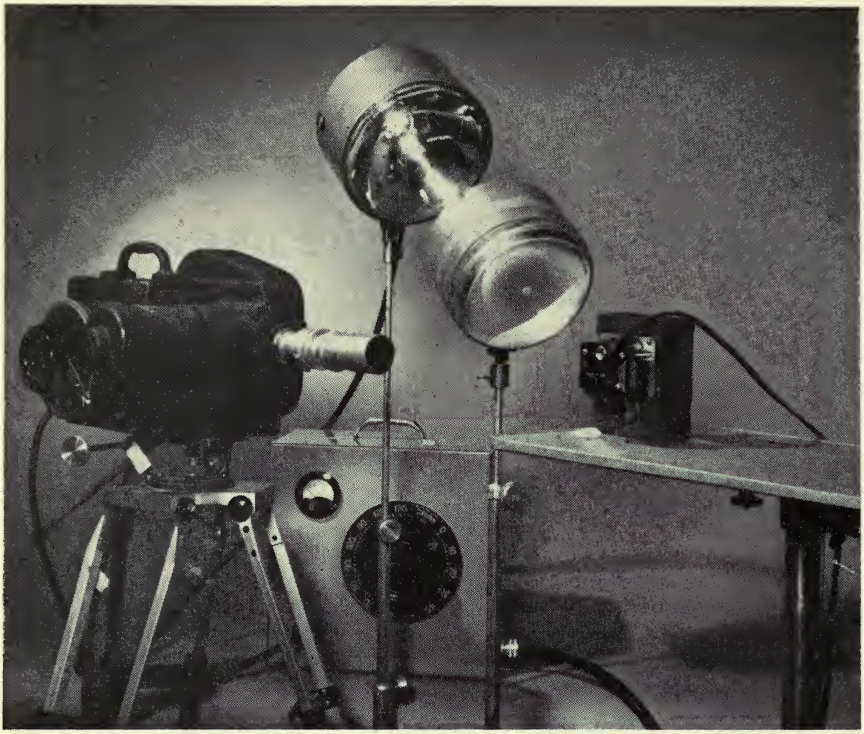


Fig. 1. Setup using the PAR 64 bulb and a condenser. The voltage to the bulb is controlled by a 20-amp variac as shown.

the subject during exposure. Many machining operations, where moving metal parts dissipate the heat, as well as clear plastics, which do not generally absorb a damaging amount of heat during the short exposure interval, can be photographed with this light. Small, rapidly moving subjects which pass through the illuminated area are, of course, a natural for this light source.

Exceptionally clear, crisp pictures can be obtained with this lamp because of the smaller lens opening and finer-grained films its use permits.

Figure 1 shows the setup using the Par 64 bulb and a condenser.

Dynamic Transfer Characteristic of a Television Film Camera Chain

By W. K. GRIMWOOD and T. G. VEAL

The relation between kinescope luminance and the illuminance on the mosaic of the iconoscope can be measured under operating conditions by the use of specially prepared slides or 16-mm films. One or more small areas in any selected scene are replaced by areas of uniform density. A series of slides or a complete film consists of a series of pictures which are all identical except for the density of these measuring areas. The television chain is adjusted for satisfactory reproduction of the scene. Measurements of the illuminances on the iconoscope in the aforementioned areas are then plotted against measurements of the kinescope luminances in the corresponding areas.

A number of transfer-characteristic curves are shown as examples of the effects of such variables as the density of the picture background, the shading control settings and the illuminance level. The differences between still and intermittent projection are illustrated by a set of transfer curves. Another group of curves shows the transfer characteristic of the photographic process, the transfer characteristic of the televising process, and the transfer characteristic of the combined film-television process.

Because of the dependence of the transfer characteristic upon the nature of the scene, no single characteristic can be considered as representing the performance of an iconoscope film camera chain.

THE TERM "transfer characteristic" is taken here to define the relation between the illuminance on the television pickup tube and the corresponding luminance of the kinescope. The adjective "dynamic" is used to indicate that the transfer characteristics are measured under actual operating conditions. This paper is concerned only with a film chain consisting of a motion picture film or slide projector, an iconoscope camera, a camera control and a studio monitor.

The calculation of transfer characteristics from published iconoscope and kinescope curves is not a very satisfactory procedure; while the kinescope characteristics are well defined, the iconoscope response cannot be defined by a single curve. Further, the published iconoscope curves are not carried to as high illumination levels as may be used in practice. For example, the *RCA Tube*

Communication No. 1421 from the Kodak Research Laboratories, presented on October 17, 1950, at the Society's Convention at Lake Placid, N.Y., by W. K. Grimwood and T. G. Veal, Kodak Research Laboratory, Rochester 4, N.Y.

Handbook curve of the RCA Type 1850-A Iconoscope ends at 20 ft-c; this is between one-fifth and one-fortieth the illumination that may be used in actual operation. Because of the uncertainty of the iconoscope characteristic, it was felt that measurements might best be made while the television film chain was carrying a picture image. There is not, unfortunately, a single transfer characteristic. Each adjustment of pedestal, gain, shading or kine brightness results in a different characteristic. In general, these controls were set for best picture quality, a criterion which is rather vague and is subject to considerable variation between individuals.

Slide Projection

In order to measure the television transfer characteristic, we have used a method developed by J. G. Streiffert, of the Kodak Research Laboratory. One or more perforations are punched in a slide of any suitable subject. Pieces punched from a film of uniform density are cemented into these perforations. A series of such slides are fabricated, the inserted "densities" being different in each slide. The slides are essentially identical prints from the same negative (except for the inserted densities), and the perforations are punched from a template so that they will be in the same area of the picture in all slides. One slide from a group of twenty-eight is shown in Fig. 1. Each slide in this group has three measuring areas: the spot in the white dress will be called spot W, the one in the black dress, B, and the one in the gray dress, G. The spots are $\frac{1}{8}$ in. in diameter and comprise about 1% of the useful area of the Retina-Camera size slide. While the area of the spots is too small to affect the response of the iconoscope to the picture signals, the

Fig. 1. Sample slide, showing measurement areas.

spots do have a noticeable effect under some conditions. If the spot densities are either higher or lower than the highest and lowest densities, respectively, in the picture, the average luminance of the picture on the kinescope will shift slightly. For the series of slides illustrated by Fig. 1, the highest and lowest densities were approximately 2.6 and 0.3, respectively. Above and below these densities there may be some question as to the accuracy of the data.

The slide projection used for these measurements was a Kodaslide Projector, Model 2A, equipped with an Ektar *f*/4.5 enlarging lens and masked to project the 3 : 4 picture ratio used in television. The television equipment was an RCA film camera chain using a Type 1850-A Iconoscope and an RCA Type 1816P4 Kinescope. Relative illuminances and luminances were measured with a Welsh Densichron. The Densichron modulates the photoelectric current by subjecting the electron stream to a 60-cps magnetic field. When the kinescope luminance is measured, this modulating field is not necessary, since the light is already modulated by the television 60-field scanning, so that a switch was installed in the Densichron to "open-circuit" the modulating field. In order to make the Densichron probe less sensitive to position when the kinescope luminance is measured, the probe was modified so as to accept only a narrow cone of light. The phototube used has an S4 surface.

In general, the measuring procedure consists in adjusting the camera controls until a satisfactory picture is obtained, using for this purpose a slide with no spots. The video level is maintained at 2 v

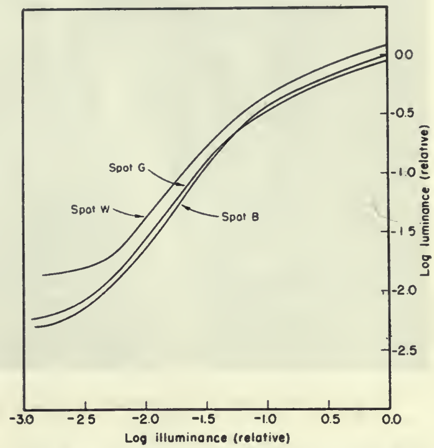


Fig. 2. Slide projection, showing effect of surround.

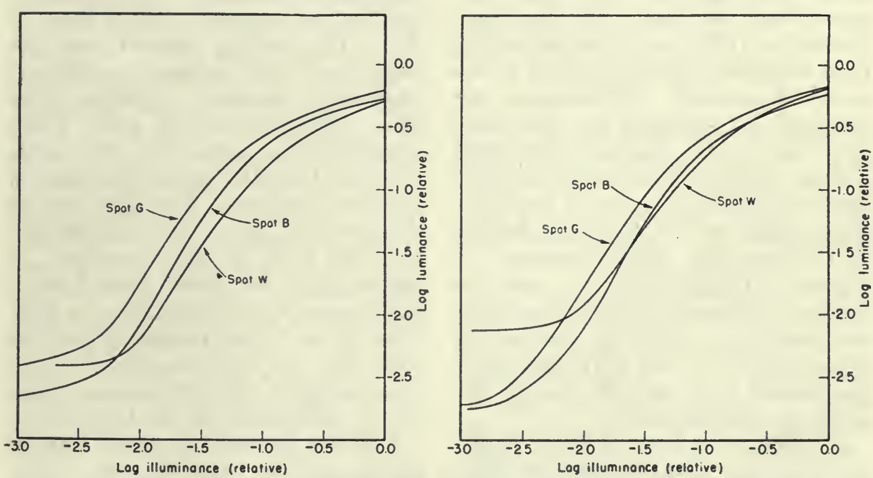


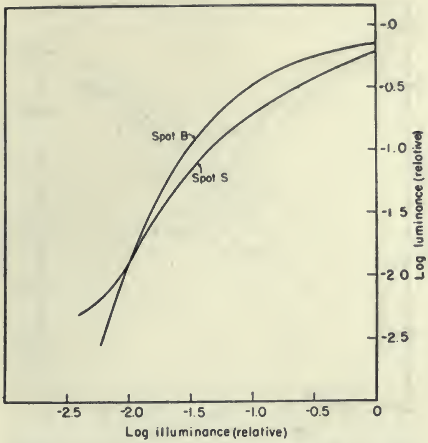
Fig. 3. Transfer characteristic, no shading; left, slide normal; right, slide reversed.

Fig. 4. Sample slide, showing gray background, and measurement areas.

peak-to-peak. Measurements are then made of the kinescope luminance in the spot areas, using the Densichron probe in contact with the face of the kinescope. The series of slides are measured and the spot luminances plotted against iconoscope illuminance. Illuminances are measured by projecting the slide series onto one of the standard Densichron probes. The probe is placed at the same distance from the projector as the iconoscope mosaic and so located that the spot area covers the probe aperture. A Macbeth Illuminometer is used to measure reference levels of illuminance and luminance. All of the slide curves, unless otherwise noted, were taken at an illuminance level, with no film in the projector, of about 800 ft-c.

A typical set of curves is shown in Fig. 2. This figure also illustrates the effect of the luminance of the area surrounding the measuring spot. The controls were set for what was judged to be good picture quality in a darkened room. Zero level on the luminance scale is about 12 ft-L. The shading controls were adjusted until the monitor cathode-ray oscilloscope showed a uniform white level. Note that spot W, which is surrounded by an essentially white area, does not have the luminance range of the other two spots. This effect may be decreased by use of the shading controls, but may not be eliminated. A similar effect, due to lens flare, is measurable upon direct projection of a slide. With the projection equipment used for these tests, the lens flare effect is, however, negligible over the range of luminances reproduced by the kinescope.

Figure 3 shows curves taken with no shading signals. The two sets of data are comparable, the only difference be-



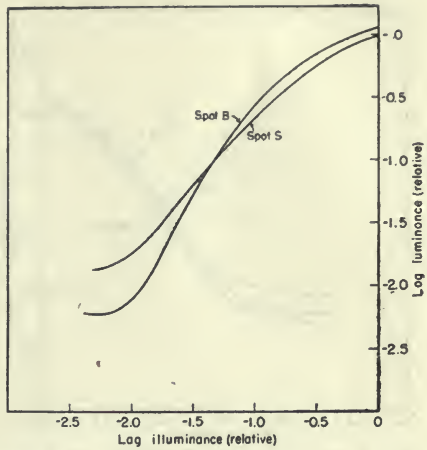
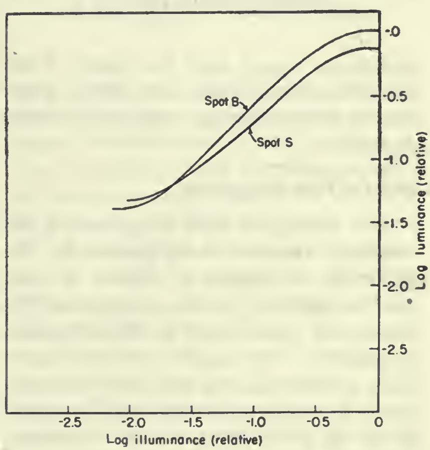


Fig. 5. Slide projection, showing progressive change of curvature and maximum slope of transfer characteristics as background changes from black (above, left) to gray (above, right) to white (right).



tween them being that that on the right was taken with the slides reversed right and left, so that spot W, normally on the left side of the picture, is, in the right part of Fig. 3, on the right side of the picture. Comparison of the two sets of curves shows only small differences between the two B curves and between the two G curves, but fairly large differences in shape and slope between the W curves.

A second series of slides was prepared with the objective of illustrating the effect of the picture background upon the transfer characteristic. These slides, one of which is reproduced in Fig. 4, were prepared from photographs of a girl in evening dress seated before a plain curtain backdrop. Three negatives were taken, in one of which the backdrop was black, in another, gray, and in the third, white. One measuring spot, designated as B, was located in the background area and another, designated as S, in the subject's shoulder. The transfer characteristic was measured on the same equipment and by the same technique as used in conjunction with the first series of slides. Pedestal, gain, brightness, and shading controls were adjusted for the most acceptable picture for each of the three backgrounds. The measured transfer characteristics are shown in Fig. 5. Zero on the luminance scale of Fig. 5 is 6 ft-L. These curves exhibit a progressive change of curvature and of maximum slope as the background is changed from black to gray to white. The transfer characteristic for the white-background pictures has a nearly linear central portion and pronounced highlight and shadow compression. The

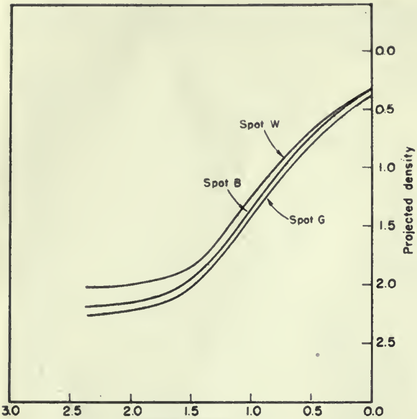


Fig. 6. Transfer characteristic of 16-mm motion picture process.

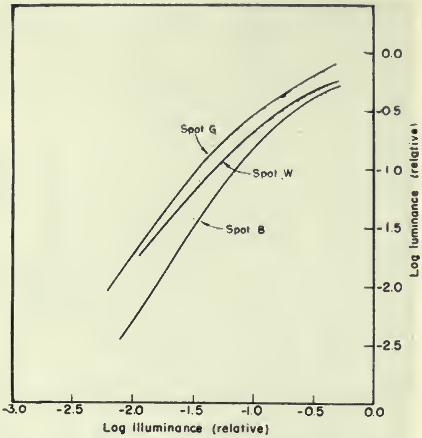


Fig. 7. Television transfer characteristic, 16-mm film projection.

luminance range and the slope of the transfer characteristic are much lower than those for the gray or the black backgrounds.

16-Mm Film Projection

The technique used in measuring the television transfer characteristic for 16-mm film projection is similar to that used for slide projection, except that the measuring areas were produced photographically. A negative of the same scene as was used for the slide measurements was enlarged from a usable size of $2\frac{3}{4}$ by $3\frac{1}{2}$ in. to 11 by 14 in. One-inch holes were punched in this positive transparency in the same locations as were used for the spot areas in the slides. The transparency was laid on an illuminator and photographed with a 16-mm camera, the holes being filled with 1-in. disks of neutral nondiffusing densities. A series of 16-mm photographs were taken, a different value of neutral density being used for each section of the 16-mm film. A contact print of the 16-mm negative was projected onto the iconoscope mosaic by the Eastman Model 250 Projector. With no film in the gate, the illuminance on the mosaic was 260 ft-c. Luminances and illuminances were measured with the Densichron in a manner similar to that described in connection with the slide measurements.

Since the 16-mm films are made by photographing a transparency in which there are inserts of known densities, data are available on the overall motion picture characteristics (including camera and projection optics) as well as on the television characteristic. Figure 6 shows the photographic characteristic and Fig. 7 is one set of curves of the television characteristic. The differences between the curves of Fig. 6 are due to unevennesses in illuminance in the taking and projection processes. These unevennesses do not enter into the curves of Fig. 7; here, the differences are chiefly associated with shading. Note that in this example the television characteristic has a greater range of luminances than the photographic process characteristic. Not all this range is usable, however, because the low luminance levels are normally masked by room lighting. While the characteristic of Fig. 7 may give somewhat poorer picture quality than that of Fig. 6, because of the greater highlight compression, either characteristic should result in acceptable tone rendition. The product of these

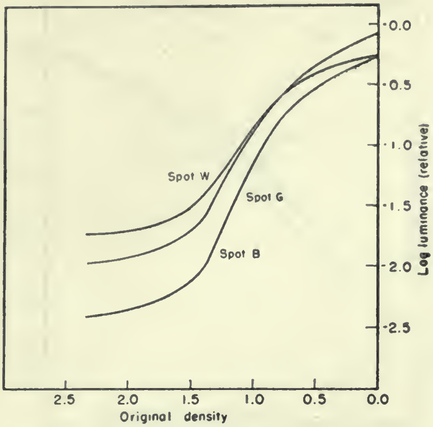


Fig. 8. Overall transfer characteristic. 16-mm motion picture process televised by iconoscope film camera chain.

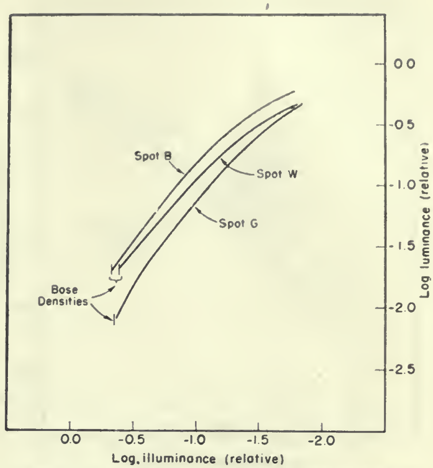


Fig. 9. Television transfer characteristic, 16-mm negative film projection.

two characteristics is, as may be expected from Fig. 8, far from satisfactory. The spread between the three curves of Fig. 8, especially in the shadow region, is not particularly significant, since it may be largely corrected by adjustment of the shading controls. In a television film chain using only linear amplifiers, little can be done to correct the severe highlight compression of the overall transfer characteristic. Readjustment of the operating controls to improve tone rendition in the highlights merely results in poor tone rendition in some other portion of the tone scale.

Figure 6 should not be taken to represent the optimum tone reproduction of the motion picture process. It does, however, illustrate the kind of characteristic which gives good picture quality. That the tone reproduction characteristic of the motion picture process is curved rather than linear, is not due to the technical inability to produce, within reasonable limits, a linear characteristic. The overall tone reproduction curve of the motion picture process is the result of the motion picture industry's years of practical experience. Any assumption that the relation between screen luminance and scene illuminance should be linear for either motion picture or television reproduction is not justified by this experience. If a television screen is to be viewed under conditions similar to the viewing of motion picture screens, the television film chain transfer characteristic should be approximately linear. (Alternatively, the television characteristic could be curved and the film characteristic linear; this would restrict the television pickup to specially made films.) The statement that the television transfer characteristic should be linear contains the implicit assumption that the material to be televised is a motion picture of good direct-projection quality. It is customary, in filming pictures for television use, to use flatter lighting than for pictures taken for distribution in theaters. Satisfactory reproduction of such material requires that the relation between the logarithm of luminance and the logarithm of illuminance be linear, with a slope greater than unity. The apparent high contrast of the television transfer characteristics shown in this paper is, in part, due to the use of original negatives taken with low-contrast lighting.

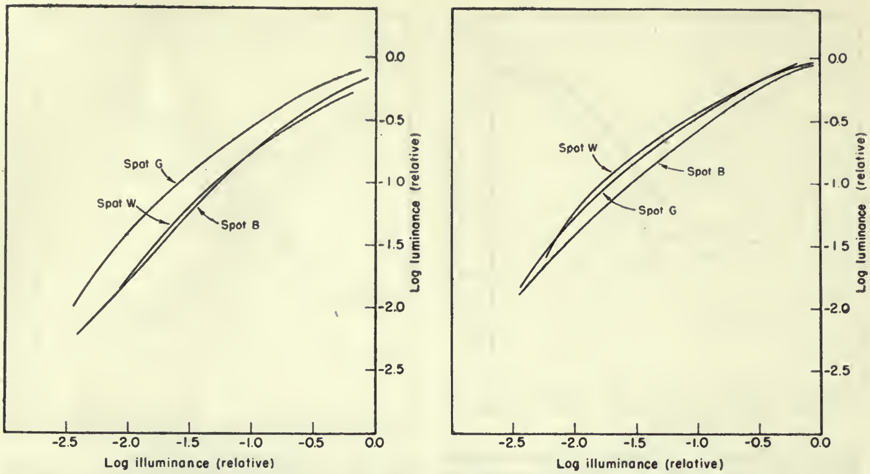


Fig. 10. Television transfer characteristic, 16-mm film projection; left, shading A; right, shading B.

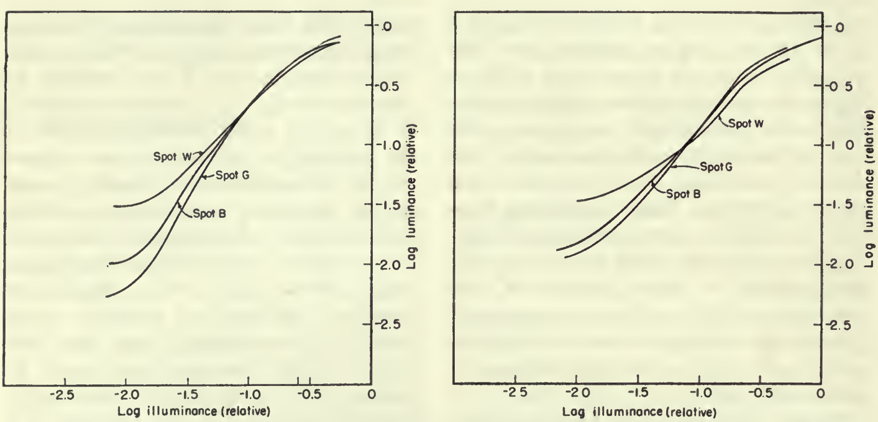
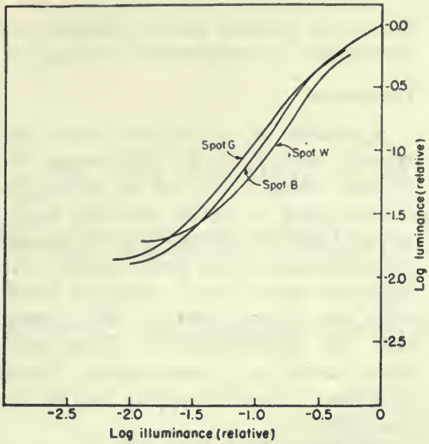


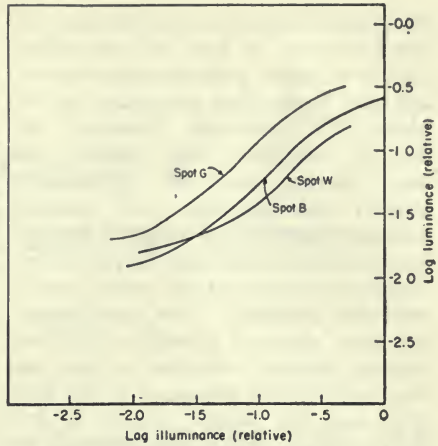
Fig. 11. Television transfer characteristic, 16-mm film projection (filtered light); left, normal illuminance; right, low illuminance.

It is well known that televising a negative over an iconoscope camera results in better picture quality than the televising of a print. While there are several reasons for the improvement, one reason is a more linear transfer characteristic, as may be seen from Fig. 9. Figure 9 is from measurements on the negative from which the print was made for the measurements plotted in Fig. 7.

Adjustment of the shading controls does not merely raise or lower the transfer characteristic relative to the luminance scale. Figure 10 illustrates the sort of change that results from even a slight readjustment of shading. The data of the left part of Fig. 10 were taken under the same conditions as the data of the right part, except for the shading-control setting. Readjustment of shading has left spot G practically unchanged. Spots B and W have been shifted upward

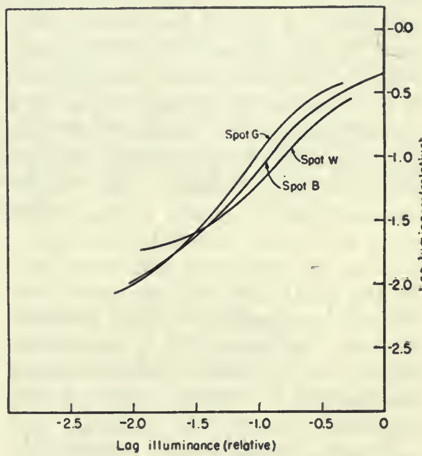


(a) Shutter stationary



(b) Shutter rotating

Fig. 12. Television transfer characteristic, 16-mm film projection (filtered light).



(c) Shutter rotating, television controls readjusted.

on the luminance scale, but at the same time their slope has been reduced. It appears to be generally true that the slope of the luminance-versus-illuminance curve is changed by the shading; in regions where shading is used to raise the average brightness, the slope is decreased, and vice versa.

The effect of illuminance level upon the transfer characteristic is illustrated by Fig. 11. Data for both sets of curves were taken with color filters in the projector condenser system. The zero of the illuminance scale for the left set of curves represents a level of 91.5 ft-c. For the right set of curves, zero level represents 91.5 ft-c attenuated by a nondiffusing neutral density of 0.7. Zero on the luminance scale is 5.6 ft-L for both figures. At each illuminance level, the television controls were adjusted to give what was considered to be the most satisfactory picture quality obtainable. The transfer characteristic measured at the lower illuminance level exhibits a shorter range of luminances and more marked highlight compression than the higher-level characteristic. These curves show only the transfer characteristic; to the operator, there is also a decided difference in case of shading in favor of the higher illuminance level.

Still-Versus-Motion Picture Projection

The transfer characteristics shown for still projection and those for motion picture projection cannot be compared directly because the picture sizes and the

illuminance levels were not the same for the two cases. It was, however, found feasible to make a direct comparison of still and intermittent projection on the Model 250 Television Projector. By placing a dichroic filter between the lamp housing and the synchronous shutter, sufficient red and infrared radiation was reflected so that a piece of heat-absorbing glass could be placed between the shutter and the second pair of condenser elements. The heat-absorbing glass absorbed enough of the remaining infrared radiation so that the film could be left stationary in the film gate, with the shutter stopped in the open position, without serious damage to the film. With the shutter rotating, the illuminance on the iconoscope mosaic was 92 ft-c by measurement with a Macbeth Illuminometer. The illuminance, with the shutter stationary, was reduced to the same measured value by placing a nondiffusing neutral density in the projection beam and slightly readjusting the projection lamp voltage. The transfer characteristics are shown in Figs. 12(a), 12(b) and 12(c). For all three figures, zero on the luminance scale is 11 ft-L. Figures 12(a) and 12(b) are taken without any readjustment of the television controls; the figures are a direct comparison of constant-versus-intermittent illumination. Without touching the brightness control, the pedestal, gain and shading controls were readjusted to give the best picture quality while maintaining the peak-to-peak video level at 2 v. Figure 12(c) is the characteristic measured after this readjustment of controls. It is evident that intermittent illumination is responsible for a large loss in contrast and luminance range and for a serious unevenness of luminance over the picture area. Most of this loss, but not all, is regained by adjustment of the controls. Although the curves for still and for intermittent projection (after adjustment of the controls) are similar in shape, the curves of Fig. 12(c) indicate poorer highlight reproduction for intermittent illumination.

Conclusion

A number of curves have been presented, each of which represents the transfer characteristic of an iconoscope camera and a studio monitor under actual operating conditions. It should be emphasized that these curves were obtained under certain specified conditions and do not furnish a firm foundation for generalizations. They have been useful in corroborating visual judgment of picture quality and of picture defects.

There is no single transfer characteristic representing the light input–light output relation in an iconoscope film chain nor can a single specification exist, so long as the transfer characteristic is a function of the distribution of the light transmitted by the subject material.

Discussion

C. R. Keith: What density steps are used in these tests?

Mr. Veal: We used 0.1 density steps in the range of 0 to 2.5.

R. O. Drew: As photographic people like to think of gamma, even in terms of television equipment, what was the overall gamma of the iconoscope, kinescope and film characteristic that you used in taking these pictures?

Mr. Grimwood: With one exception the curves do not include the film characteristic. Most of the curves have no linear portion so there is no gamma in the photographic sense. The maximum slope in the mid-portion of these curves is likely to be higher than that of a curve having a long linear region. This is a compromise which must be made to obtain some semblance of tone scale in the end portions of the curves. In addition, the slope of the transfer characteristic is partly a compensation for the low-contrast lighting that is frequently used in producing film for televising.

Use of Color Filters in a Television Film Camera Chain

By W. K. GRIMWOOD and T. G. VEAL

The quality of pictures televised by an iconoscope film camera is improved by removing the red and infrared portions of the radiation incident upon the mosaic of the iconoscope. The combination of heat-absorbing glass with either an absorption or a reflection type of color filter can be used in the condenser optical system of a 16-mm projector. Such a combination of filters reduces the heat at the film gate enough to permit the film to be held stationary in the gate without damage to the film. The color filters improve picture sharpness, reduce shading requirements, and increase the signal level. The improvement in sharpness is partly an optical effect. The increase in signal level, despite the reduction of photoactive radiation, is believed to be an electronic effect peculiar to the iconoscope principle.

IT HAS BEEN FOUND that the quality of pictures produced by a television film chain is improved if the red and infrared components are removed from the radiation incident upon the mosaic of the iconoscope. Experimental work with a number of color filters, of which the three curves of Fig. 1 are illustrative, was carried out on the Eastman 16-Mm Television Projector, Model 250. The light source of this projector is a tungsten lamp operated at about 3400 K. The greatest improvement in picture quality was observed when using the filter defined by curve 2 in Fig. 1. This combination of a 6-mm thickness of Pittsburgh No. 2043 Glass (heat-absorbing) and a 3-mm thickness of Corning No. 9780 Filter is recommended for use in the Model 250 Projector. Figure 2 shows the location of the two filter glasses between the synchronous shutter and the film plane. This location necessitates the use of the heat-absorbing glass, the sole function of which is to reduce the infrared energy in the projection beam so that there is no danger of breakage of the Corning filter from heat absorption. Placing the filters between the shutter and the film is preferable to inserting the filters between the projection lens and the iconoscope, for several reasons. The latter choice is undesirable because it injects the possibility of image degradation due to optical imper-

Communication No. 1409 from the Kodak Research Laboratories, a paper presented on October 17, 1950, at the Society's Convention at Lake Placid, N.Y., by W. K. Grimwood and T. G. Veal, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y.

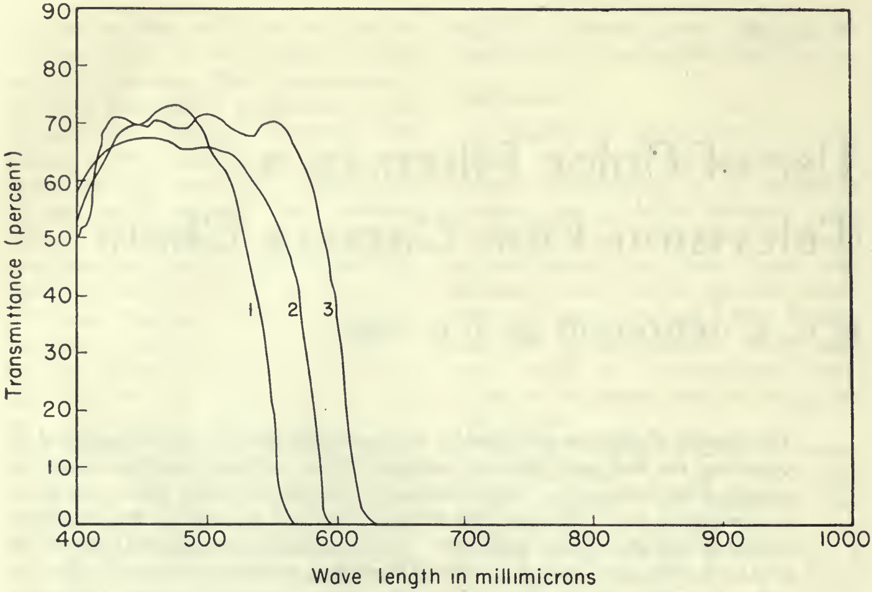


Fig. 1. Spectrophotometric curves of filters used in 16-mm television projector: Curve 1, dichroic No. 1 plus Pittsburgh No. 2043, 4 mm thick; curve 2, Corning No. 9780, 3 mm thick plus Pittsburgh No. 2043, 6 mm thick; curve 3, dichroic No. 2 plus Pittsburgh No. 2043, 4 mm thick.

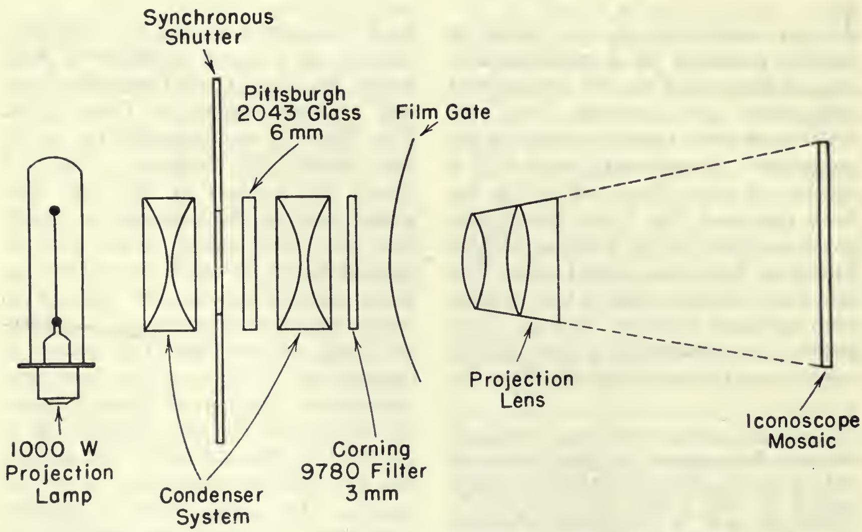


Fig. 2. Eastman Model 250 Projector optical system.

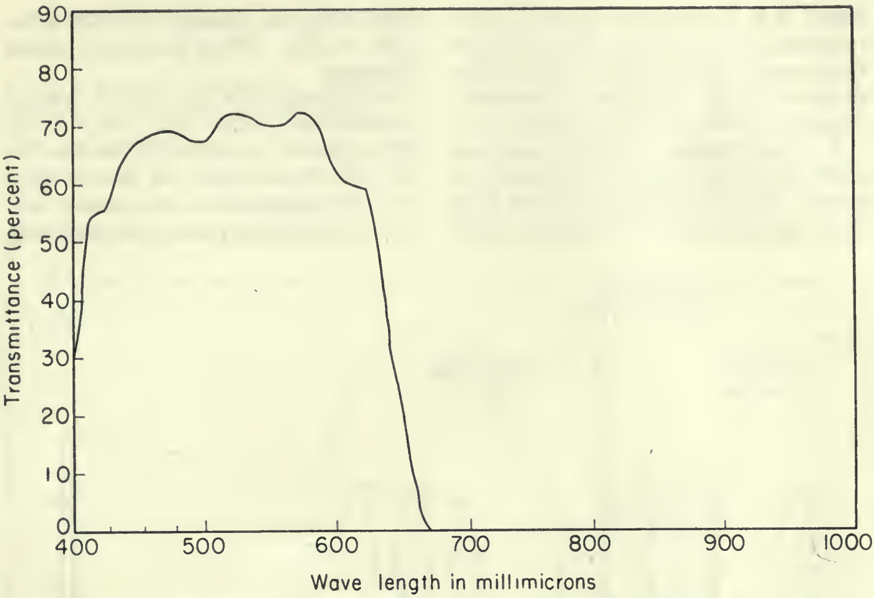


Fig. 3. Spectrophotometric curve of filters used in 16-mm projector of 100 ft-c illuminance. Dichroic filter plus Pittsburgh No. 2043, 4 mm thick.

fections in the filter glass, or to accumulation of dust on the filter surfaces. The filter itself is more exposed to accidental breakage. The most compelling reason, however, is that when the filters are located in the condenser system, the film can be left stationary in the film gate (with the shutter operating) for an indefinite period without buckling. The radiant flux at the film gate is 0.55 mw/sq cm, one seventeenth of the unfiltered value. The filters absorb about 35% of the energy within their passband and have a transmittance of 10% at 590 mμ.

With a projector illuminance of 250 ft-c, the loss of photoactive light by filter absorption is not serious, but with a projector illuminance of the order of 100 ft-c, this absorption becomes a more important factor. Furthermore, glass filters occupy appreciable space which may not be available in a projector condenser system. In such situations, the dichroic or interference type of filter is therefore useful. The dichroic filter not only has low loss in the transmitted band, but removes unwanted radiation by reflection rather than by absorption. The latter property makes it possible to coat the dichroic filter directly on the rear element of the condenser optics. A disadvantage of the dichroic filter is its band-elimination type of characteristic, that is, the transmittance drops to a level of perhaps one quarter to one half of 1% in the red, but at still longer wavelengths the transmittance increases rapidly. Fortunately, Pittsburgh No. 2043 Glass has sufficient absorption in the region where the dichroic filter fails, so that the combination of this glass and the dichroic filter results in a satisfactory filter. Figure 3 shows the absorption curve of a dichroic filter plus a 4-mm thickness of the heat-absorbing glass (Pittsburgh No. 2043). For this combination, the 10% transmittance point is at 640 mμ; thus, there is less loss of photoactive light with this filter than with that described by curve 2 of Fig. 1.

Figure 4 is a schematic drawing of the projector optical system for which this filter was designed. The location of the dichroic coating and of the heat-absorbing glass is indicated in the figure.

For best results, the edge and bias lights in the film camera should also be filtered. Since little heat radiates from these light sources, the filtering may be done with 2-in. squares of Corning No. 9780 or No. 9788 Filters in a 3-mm thickness.

Measurements of the dynamic transfer characteristic, taken with and without filters, do not satisfactorily indicate the observed improvement in picture quality. If measurements are made with and without filters, but with no change

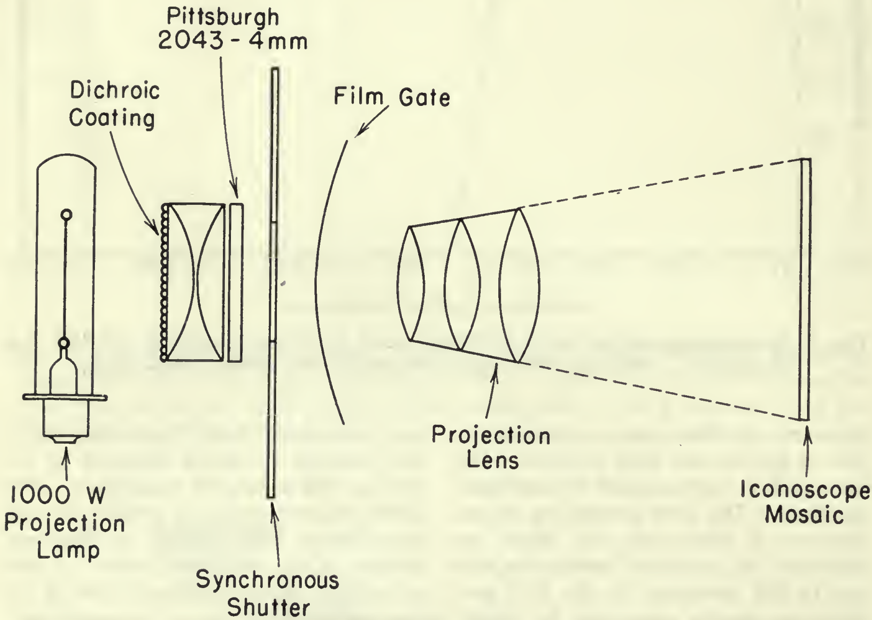


Fig. 4. Projector optical system.

Fig. 5. Photographs of the monitor kinescope images. Photographs from the same frame of a normal 16-mm print. Left, with filters; right, without filters.

in the television controls, there will be a distinct difference in the curves. This is not a legitimate technique, since the insertion of the filters changes the signal level and the shading. The signal level increases and the contrast increases, but these changes may also be produced in the unfiltered picture by manipulation of the gain and pedestal controls. When pedestal, gain and shading have been readjusted to produce an unfiltered picture which visually matches the filtered picture, then the transfer characteristic curves have been so modified that it is not possible to ascribe specifically any difference in shape to the filters. Small differences in the critical highlight region

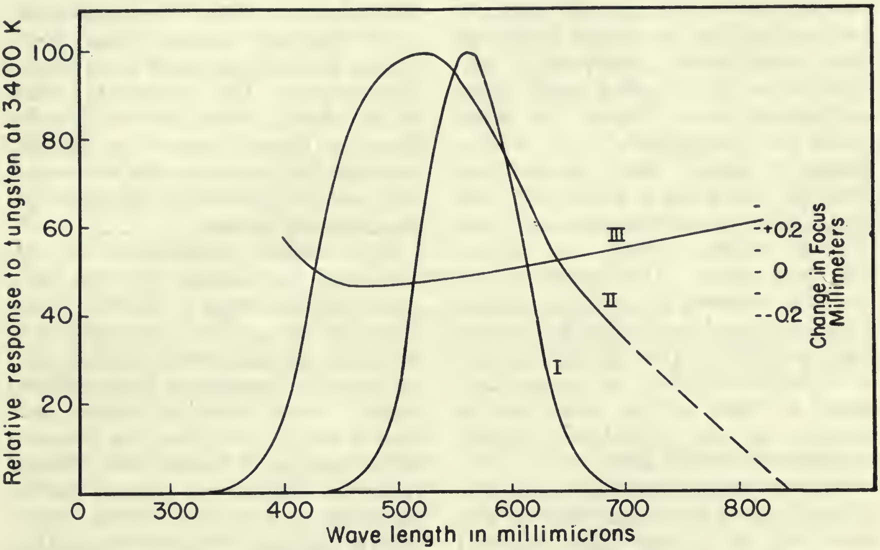


Fig. 6. Relative response to tungsten at 3400 K.

I, average human eye; II, Type 1850-A iconoscope; III, chromatic aberration of 3-in. Projection Ektar with television 12× attachment (use right-hand ordinate scale).

Fig. 7. Photograph of the kinescope monitor image (black-and-white) reproducing a picture projected from 16-mm Kodachrome original. Left, filtered picture; right, unfiltered picture.

are especially likely to be masked by shading-control adjustments.

Although the effects of color filters are not obvious from transfer characteristic measurements, the effects are readily perceived upon visual examination. With filters installed in the projector and in the television film camera, the most noticeable change in the picture is a reduction of the haze or veil which is characteristic of televised film pictures, and an increase in picture sharpness. The improvement in sharpness is most apparent in the increased detail visible in highlight areas. Figure 5 is reproduced from photographs of the monitor kinescope image. Both pictures are from the same frame of a normal 16-mm print. The picture on the right was televised without filters; that on the left, with filters. The television controls were adjusted to match the pictures visually as closely as possible for contrast and brightness. The left-hand picture is definitely sharper in appearance; detail is visible in the latter that is missing in the right-hand picture, especially in the hat area.

That the improvement in sharpness is, in part, an optical effect, can be seen from Fig. 6. In this figure, curve I represents the spectral response of the average human eye to tungsten illumination; curve II is the spectral response of the Type 1850-A iconoscope to tungsten light, as calculated from the response curve published in the *RCA Tube Handbook* (extrapolated to 800 mμ); and curve III is the chromatic aberration curve of the projection lens used in the Eastman Model 250 Projector. Visually, this is an excellent projection lens; no discernible shift in visual focus results from the insertion of the television filters (Fig. 1). The eye, however, is relatively uncritical of the sharpness of the red and blue components of the image, owing to the low luminosity of these components and to the chromatic aberration of the eye. Since a considerable portion of the iconoscope response lies in the red and infrared regions, where the focal plane of the lens does not coincide with that of the green, it is reasonable to expect the sharpness of televised pictures to be improved by the removal of this red and infrared radiation.

The most striking improvement in picture quality is found in the televising, in black-and-white, of color film such as Kodachrome. Figure 7 is a photograph of the kinescope monitor image reproducing a picture projected from 16-mm Kodachrome. The unfiltered picture on the right is much lower in contrast than the filtered picture on the left, although this represents the best match that could be obtained by adjustment of the operating controls.

The marked improvement in the quality of Kodachrome pictures, when the projection beam is filtered, is due largely to the spectral characteristics of the image-forming dyes. Organic dyes are generally transparent in the infrared region. When unfiltered tungsten radiation is used for projection, the mosaic of the iconoscope is flooded with infrared radiation carrying no image, but to which there is an appreciable photoelectric response. A similar degradation of picture quality can be produced when projecting silver images by uniformly illuminating the mosaic with a small amount of radiation from an auxiliary light source.

A major advantage in using filters is a decrease in shading requirements. The scene-to-scene changes in shading, when projecting motion pictures, are reduced to such an extent that shading readjustments are necessary only when there are radical changes in the distribution of light and dark areas in the picture.

The improvement in shading appears to be associated with an increase in signal level. The insertion of filters in the Model 250 Projector is accompanied by an *increase* in the signal as indicated by the monitoring cathode-ray tube, although calculations from the published

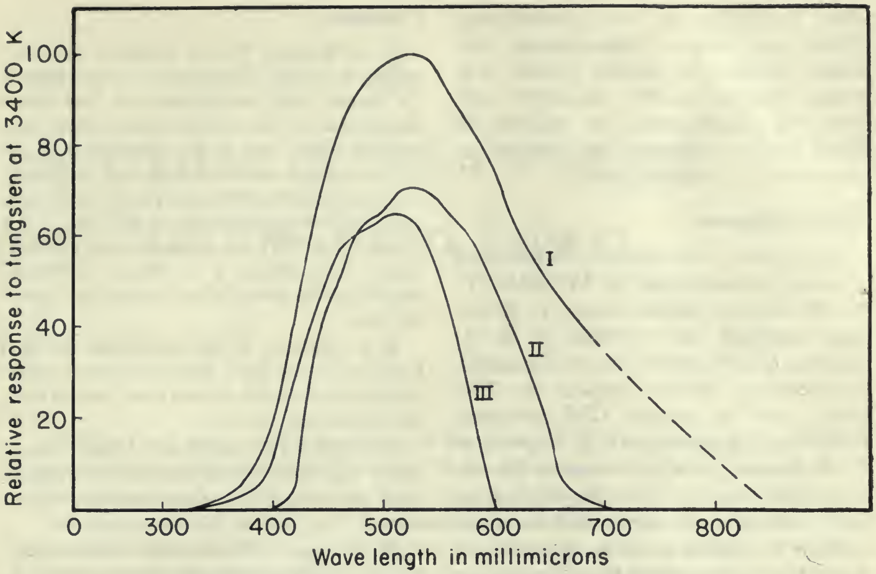


Fig. 8. Relative response to tungsten at 3400 K.

I, Type 1580-A iconoscope; II, iconoscope with dichroic filter and 4 mm of Pittsburgh No. 2043 Glass; III, iconoscope with 3 mm of Corning No. 9780 Filter and 6 mm of Pittsburgh No. 2043 Glass.

spectral-response curve of the iconoscope show that the photoactive light is reduced by the filters to only about 40% of the unfiltered value. The increase in signal level is approximately 20%.

Figure 8 shows the spectral response of the iconoscope to tungsten radiation at 3400 K (curve I), the response of the iconoscope with the dichroic filter combination (curve II), and the response of the iconoscope with the glass filters (curve III). Although the total photoactive radiation is reduced by filtering, as shown by the relative areas of these three curves, the average velocity of primary electron emission from the mosaic is increased, since the velocity of emission is greater for the shorter wavelengths. Higher average velocity should increase the distance between the space charge and the mosaic, so that fewer electrons are repelled by the space charge and fewer are lost by the space charge to the mosaic. It follows that the output level could reasonably be higher and the shading problem lessened by this action. Some improvement in highlight resolution could also be expected.

The improvement in picture quality resulting from the use of filters varies from one iconoscope to another. The differences in results are probably largely due to variations in the response to red and infrared, relative to the response to blue among iconoscopes. The edge-light filter which usually reduces edge flare has little effect with some iconoscopes, and has little or no effect when low-illuminance edge lighting is used. The bias-light filter normally results in a less critical bias-light adjustment for application-bar cancellation, but frequently has no appreciable effect. Filtering the projection beam nearly always results in a worth-while improvement in picture quality, but the degree of improvement is less when filters are used

with projectors of low illuminance. Within the range of illuminances currently obtained in motion picture projection, picture quality improves with increased illumination; the addition of filters further improves the quality by producing a sharper picture.

Acknowledgment

Filters have been used in commercial television broadcasting by WHAM-TV, the Stromberg-Carlson station in Rochester, through the kindness of K. J. Gardner of that station, by the Columbia Broadcasting System station in New York, and by several CBS affiliates. We are most grateful to H. A. Chinn and K. B. Benson, of the Columbia Broadcasting System, for their cooperation in field trials of these filters and for their courtesy in passing on to us the results of their field experience from numerous filter installations.

We wish also to acknowledge the contributions of George Koch, Development Dept., Camera Works, Eastman Kodak Co., who made the dichroic filters used in their experiments, and those of numerous members of the Research Laboratory staff.

Discussion

E. W. Kellogg: Was it necessary that the visible red light be removed by the filters? Of course, that would seem to put some limitations on the applicability when you get into color, but as you illustrated when reproducing a color original, I noticed that the transmission characteristics of the filters you used cut considerably in the red.

Mr. Veal: We do remove all the red light. The object is to obtain optimum results for black-and-white television reproduction.

R. L. Garman: Is the ultraviolet cut out because of lens flare, fluorescence and that sort of thing, or is it for the same reason that the infrared is cut out?

Mr. Veal: The reduction of the ultraviolet was not deliberate, but the filters used removed part of the ultraviolet radiation.

H. M. Gurin: Has any effort been made to use a light source in which the red is absent, so that the use of filters could be avoided?

Mr. Veal: The GE pulsed light source is widely used. With the new FT231 lamp it is unlikely that there would be much improvement when reproducing a black-and-white picture. The use of filters would be advisable when reproducing a color picture in black-and-white.

Duplication of Color Images With Narrow-Band Filters

By RODGER J. ROSS

Outlined are some of the problems of the users of direct-positive subtractive color films, such as Ansco Color and Kodachrome, in producing acceptable duplicate images which in some cases may be third-generation reproductions. An experimental project will be described in which it was found that it is possible to produce duplicate images which may be directly compared with the camera originals by exposing the duplicating film with filters transmitting three relatively narrow spectral bands. While no attempt has been made in this paper to deal in any detail with the theoretical aspects of color reproduction, a number of factors which are of great concern to the users of color materials have been noted — particularly the establishment of visual acceptance limits for color images, and the influence of processing upon the shape and relationship of the three-color density curves representing an image of a neutral wedge.

In the normal white-light printing of color film, deliberate alteration of the color balance may be employed to produce duplicate images which are quite satisfactory for some purposes. In the hands of a skillful technician, the results which can be achieved in this way are quite surprising. For instance, large numbers of excellent 16-mm motion picture prints have been produced by direct printing from the camera originals.[1,2]

The problems involved in the reproduction of larger still transparencies are considerably more severe. Here it is possible for the observer to relate the appearance of individual colors in an image to objects in the immediate vicinity, or to make side-by-side comparison of images. In addition, there is ample opportunity for leisurely evaluation of different image areas.

The appearance of a color image is often described by the term "color balance." This term is at best an uncertain indication of the characteristics of a color image, for it is well known that color balance may be influenced by such factors as the conditions of viewing. Visual evaluation, while suggesting the direction in which correction should be made, provides no indication of the degree of correction required, or the

Presented on April 30, 1951, at the Society's Convention at New York, by Rodger J. Ross, Special Effects Div., National Film Board of Canada, John Street, Ottawa, Ontario, Canada.

nature and extent of the factors which are responsible for unsatisfactory appearance.

In any attempt to improve the quality or appearance of color images, it is very difficult to demonstrate conclusively the degree of improvement that is obtained in a particular case. The best that can be done is to say that, as a result of visual evaluation, the image is a pleasing representation of the original object or scene, or that a duplicate image closely resembles the original image from which it was made. This might be defined as a process of establishing acceptance limits within which satisfactory images may be obtained. Since the eye is particularly sensitive to differences in colors in side-by-side comparisons, the acceptance limits established in direct comparison of duplicate and original color images might be expected to be severely restricted, as opposed to a condition under which an image is evaluated in respect to its pleasing appearance.

The Color Sensitometry Subcommittee of this Society, in a report published in the JOURNAL,[3] describes the progress that has been made in extending black-and-white sensitometric procedures to the evaluation of color materials and color images. One of the requirements of a color process might be said to be the reproduction of a neutral gray scale or wedge as a neutral image. The image of a neutral wedge might be represented by three curves on graph paper, derived from color density measurements on the image. Any system of this kind, however, must take into account the differences in the effects of a color image upon the eye and its influence upon another color material when duplicates must be made. There is the problem, too, of representing just-visible differences between color images of objects or scenes by significant quantitative differences in measurements upon a wedge image. Furthermore, a neutral image of a wedge is by no means an absolute requirement of a visually satisfactory image of a colored object. It should be possible eventually, however, to describe a color image in terms of a series of numbers, or as patterns upon a chart or graph paper, and to apply this information in the control of exposure and processing of color materials, in order to ensure that an image will be obtained within the acceptance limits established as a result of visual evaluation.

The deficiencies of the dyes of subtractive color materials have been described in detail in the literature. In brief, it may be said that as the result of the unsatisfactory transmissions and absorptions of available dyes, the colors in duplicate images will become degraded or desaturated.[4] In addition, the contrast of a color image must be relatively high to obtain satisfactory color saturation.[5,6] When a color image such as this must be reproduced on another color material with similar contrast characteristics, the contrast of the duplicate image will be further increased. Masking has been recommended as at least a partial solution for these problems. While it has been shown that it is possible to overcome completely the deficiencies of the subtractive process by masking, this would require the use of multiple masks. It is seldom practical, however, to utilize more than one mask in duplication. The practical difficulties involved in making and registering even a single mask have limited the use of masking procedures, particularly in motion picture printing.

Requirements for Two Languages

A basic problem of the National Film Board of Canada is the production of 16-mm color films in English- and French-language versions — one of which must be printed from color masters. When the Technical Research Division first undertook a study of the problems of color reproduction in the autumn of 1947, it appeared that no worth-while

contribution could be made by further work on conventional color-correction methods. The possibilities were considered, however, of reproducing color film with three narrow spectral bands instead of white light. The idea of printing color film in this way was not a new one, even at that time. The Schinzels had proposed in 1937 that positive color prints might be made in this way from Agfa color negatives.[7] Dufaycolor, an additive process, was being printed with three filters.[8] Since then, however, interest in three-filter exposure techniques, especially in motion picture printing, has increased. Eastman Kodak has recommended recently that positive color prints from their new color negative should be produced in this way. Kendall was one of the first to propose that direct-positive subtractive color film might be printed with three filters instead of white light, and described a modified 16-mm step printer which could be used for this purpose.[9] No attempt had been made before this project was initiated, however, to determine the most suitable spectral bands or the degree of improvement which might be obtained with this method of exposure.

The results of the experimental work on this project over the past three years would indicate that this method of reproducing direct-positive subtractive color images has some important advantages. The reproduction of individual colors can be improved and it is possible to exercise considerable control over image contrast. It is very difficult, as previously noted, to specify the exact degree of improvement that may be obtained. Since dye deficiencies are merely reduced and not entirely eliminated by this method of reproduction, duplicate images, identical with the camera originals, cannot be obtained. However, demonstration material has been assembled to indicate that duplicate images representing average objects or scenes may be made to fall within the most critical acceptance limits referred to previously — and it is often difficult to select the camera original. In comparisons of this kind, image contrast is an important factor. Although it may not always be necessary or desirable to do so, the contrast of duplicate images may be reduced by variation of processing until it is actually lower than that of the original, with no adverse effects upon the acceptance limits.

The eye is influenced by color images in such a way that color arrangement is an important factor in obtaining satisfactory duplicate images. In the course of this project it was found that if the original image contains a significant red area, for instance, there may be some degradation or alteration of this area in the duplicate image, and the failure of the process to reproduce this color is immediately apparent. The same degree of degradation or alteration will be present, of course, in all duplicate images produced in the same way, but may not influence the acceptance limits. In determining the most favorable color balance, a number of camera originals with widely different color arrangements should be selected, and with this method of reproduction a balance may be found which is satisfactory for all average scenes, eliminating the necessity for scene-to-scene correction. Further alteration of color balance will not as a rule improve the appearance of duplicates which do not fall within the acceptance limits.

The filters which have been used in the experimental work transmit relatively narrow spectral bands (Fig. 1). The object of this exposure method is to produce an image with each filter which is confined to a single layer of the duplicating film. Therefore, the transmission bands of the filters must be selected and the widths of the bands must be restricted so that this objective may be achieved.

When a color image has been produced by exposure in a camera, it should no longer be necessary to consider this

image in the same sense as an original scene for the purposes of further reproduction, but rather as a set of three dye images into which the scene has been separated. The object in duplication, then, is to transfer each individual dye image to the corresponding layer in the duplicating film. Because of the undesirable transmitting and absorbing characteristics of the color-film dyes, there must always be more or less dye in the various areas in the corresponding layers of the duplicating film than in the three layers of the original image.

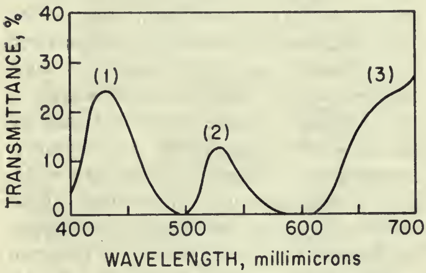


Fig. 1. The filters that have been used in the experimental work on the color duplication project.

When exposure is made with suitable filters, the light transmitted by the three superimposed dye images of the original film will be modified to that which will pass through these filters (Fig. 2).

The transmission of the magenta dye in a color film for red, green and blue is not sharply defined, but passes gradually from one color to another. For a given sensitivity band of the green-sensitive layer of a duplicating film, then, the effective green transmission of the magenta layer may be much greater than it might appear to be. It would seem to be obvious that, since the starting point in color degradation and distortion is to be found in this unwanted green transmission, considerable improvement should be obtained by restricting the transmission of the magenta dye in the green region by means of a narrow-band filter.

The possibility of lowering the contrast of duplicate images by alteration of the processing times was also explored. It was found that the processing times for Ansco Color film exposed with three filters could be reduced by as much as

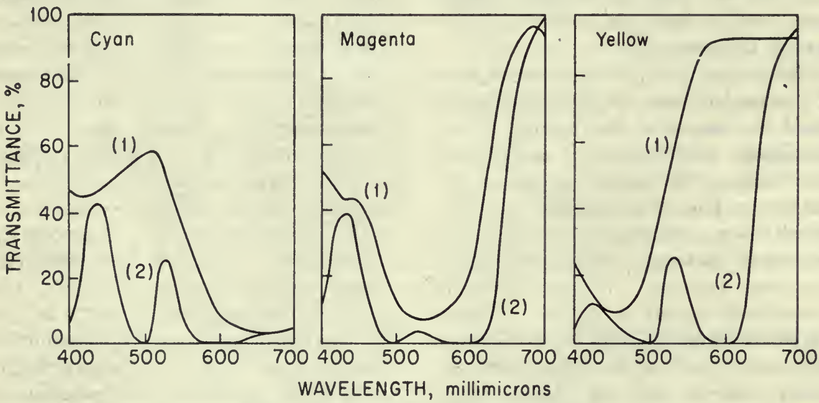


Fig. 2. Spectrophotometric curves.

Curves indicated by (1) were supplied, in each case, by the Kodak Company as representative of the Kodachrome dyes. The curves indicated by (2) were calculated (×4)from data supplied by Kodak on the dyes and the filters selected for the three-filter process. The transmission of the cyan dye in the red, the magenta dye in the green, and the yellow dye in the blue is, of course, undesirable, and if this could be eliminated it should be possible to produce identical duplicate images.

30% from the recommended times, with no apparent adverse effects on the appearance of the duplicate images. Under these conditions, the contrast of the duplicates was somewhat lower than that of the original camera images. However, in lowering the contrast of duplicate images it is very important that the higher densities should be very nearly visually neutral — otherwise undesirable alterations in the appearance of the images will be introduced.

While it was not possible in this project to study in detail the influence of variations in processing times upon the color images, it is known that processing is a significant factor in determining the shape and relationship of the three-color density curves representing an image of a neutral wedge (Fig. 3). This aspect of color-image formation has received little attention in the literature, although the effects of variations in time of first development have been described in some detail by Morse.[10]

In addition, the precise control of color processing is not a simple matter.[11] Slight variations in the constitution of the color developer will exert a strong influence upon color images, and the influence of a particular processing condition may not be the same with different color materials.[12] When a small quantity of color developer is used to process exposed film, changes in the developer between two successive tests may be responsible for a change in the appearance of the duplicate images equal to a variation of 10% in the exposure for one of the filters.

There are, of course, some practical difficulties in applying the three-filter exposure technique in the reproduction of color images. When the exposure system consists of a white-light source with a particular spectral distribution, the illumination or the exposure time may be adjusted so that images will be obtained at a level suitable for viewing or projection, and the spectral distribution of the source may be altered to obtain the desired color balance by means of voltage changes or color-compensating filters. With a three-filter exposure

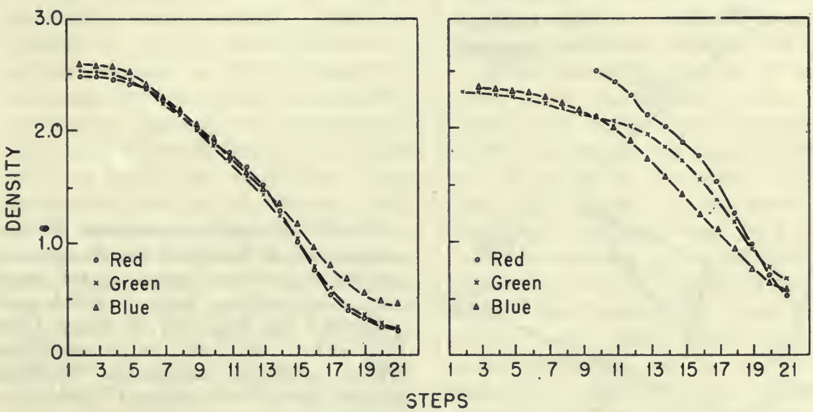


Fig. 3. Color density curves on Ansco Color film.

Left, under controlled processing conditions with which satisfactory demonstration material was produced, i.e., originals and duplicates which could be compared side by side;

Right, conditions representative of commercial motion picture processing, with which it would be impossible to produce duplicate images falling within the acceptance limits of side-by-side comparison.

system in which the light transmitted by each filter presumably affects only a single layer of the film, a different set of conditions must be fulfilled. While it is somewhat more difficult to establish the desired color balance and image level with an exposure system of this kind, it is much more flexible. For instance, tungsten or daylight-type color films may be exposed with the same system by suitably adjusting the ratio of the three-filter exposures. For the most critical purposes, this is a precise procedure compared to the use of color-compensating filters.

The method of exposure also presents some problems. In the reproduction of still images, successive exposures with the three filters may be made. Kendall has described a 16-mm motion picture printer[9] employing an integrating prism and a three-filter exposure system in which narrow-band filters could be used. A single light source could be employed with some means for alternating the filters in the light beam. A number of methods might be used to alter the time or intensity of exposure through each filter to vary the color balance. It should also be possible to employ monochromatic illumination in which case the desired spectral lines or bands might be selected by filters or slits.

The three-filter exposure system has been used to produce duplicates of large still color images that are satisfactory for viewing or further reproduction. A somewhat unusual and successful application for this exposure method was found in the production of 35-mm color-film strips from 16-mm motion picture frames. These "cine-strips" are made in an optical apparatus in which provision is made for exposure through three filters. The color master obtained in this way was printed in a step printer, the lamphouse of which had been modified to expose the third-generation duplicates in the same manner. The three-filter exposure system has also been used successfully by the Banting and Best Institute, University of Toronto, to reproduce medical photomicrographs and color transparencies in which any

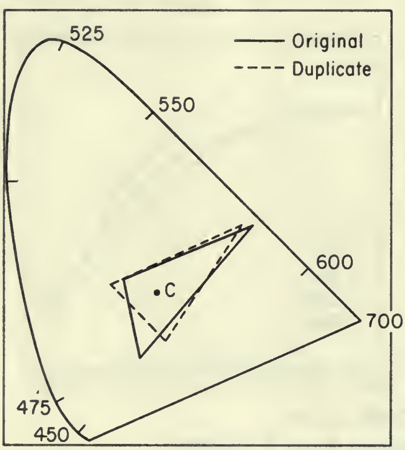


Fig. 4. Chromaticity diagram giving a comparison of dominant wavelength and excitation purity of original and duplicate color patches, both of which were produced by exposure of Ansco Color film with three filters, under conditions which produced acceptable duplicate images (from International Commission on Illumination).

	Yellow		Magenta		Cyan	
	Orig.	Dup.	Orig.	Dup.	Orig.	Dup.
Dominant wavelength	581.9	581.5	559.6C	540.0C	495.5	493.0
Excitation purity	91.00%	87.00%	49.7%	44.0%	23.9%	33.2%
Relative brightness	36.67%	31.32%	4.817%	3.967%	28.65%	16.02%

alteration in color or contrast is particularly undesirable.

The three-filter exposure method is not limited to the reproduction of stills, as has been demonstrated in the continuous printing of film strips in a motion picture printer. The techniques of white-light release printing of motion picture color film, however, have been developed to the point where fairly satisfactory prints may be produced from good-quality camera originals. Any new technique which presents new problems might not prove to be technically or economically practical, in spite of the possibility of further improvements in color quality and contrast. When adequate means have been devised to control printing and processing operations by means of color sensitometric procedures, precise printing methods such as the three-filter exposure technique should prove to be of great value in improving the quality of color release prints.

There is one application in motion picture printing in which the three-filter exposure technique should prove to be particularly useful, however. The intercutting of optical intermediates with camera originals is seldom satisfactory, and such alternatives as A & B printing, and special apparatus for obtaining simple optical effects direct from the camera originals must be employed. Intermediates suitable for intercutting should match the camera originals as closely as possible in color balance, the appearance of individual colors, image level and contrast. It has been shown that duplicate images with these desirable characteristics can be produced with the three-filter process. The problems involved in establishing and maintaining processing conditions, in order that motion picture intermediates with these characteristics may be produced consistently, are such that the closest collaboration with the processing laboratory is required. Facilities for processing lengths of film suitable for screening were not available for this project, and while considerable experimental work has been directed toward the production of optical intermediates, the demonstration material is limited to still images.

Some attention was directed, in the course of this project, to the quantitative evaluation of changes in color balance due to variations in the three-filter exposures, but a satisfactory method for indicating just-visible differences in the appearance of duplicate images has not been found (Fig. 4). The nature and extent of correction, in terms of percentage variation of the filter exposures required to obtain the desired results, was estimated by visual evaluation of comparison images. This is unquestionably a very tedious and uncertain method, and much experimental work is involved in obtaining the best possible results. From the standpoint of the users of subtractive color films, it would be desirable to find some means of establishing acceptance limits for color images, and of interpreting these limits in terms of the nature and extent of the variations in exposure and in the processing conditions which might be required to produce images consistently within these limits.

When Ansco Color film is exposed with three narrow-band filters, there appears to be increased sensitivity to slight changes in the characteristics of the film and in processing. If this is true, this method of exposure might prove to be an advantage, in a form of color sensitometry, in detecting and evaluating film and processing variations of little significance under normal conditions of use. There would seem to be some advantage, too, in utilizing the three-filter exposure system to set up reproducible color exposure conditions which could be readily specified and which should require little maintenance. While variations in the spectral distribution of a light source, now commonly expressed in terms of color temperature, will influence the film whether exposure is made with white light or with narrow-

band filters, it should be possible to specify more precisely the characteristics of an exposure system in relation to the energy in these three bands of the spectrum.

References

1. W. H. Offenhauser, Jr., "Duplication of integral tripac color films," *Jour. SMPE*, vol. 45, pp. 113–134, Aug. 1945.
2. P. S. Aex, "A photoelectric method for determining color balance of 16-mm Kodachrome duplicating printers," *Jour. SMPE*, vol. 49, pp. 425–430, Nov. 1947.
3. Report of the Color Sensitometry Subcommittee, "Principles of color sensitometry," *Jour. SMPTE*, vol. 54, pp. 653–724, June 1950.
4. T. H. Miller, "Masking: a technique for improving the quality of color reproduction," *Jour. SMPE*, vol. 52, pp. 133–155, Feb. 1949.
5. R. H. Bingham, "Sensitometric evaluation of reversible color film," *Jour. SMPE*, vol. 46, pp. 368–378, May 1946.
6. W. T. Hanson, Jr., and F. A. Richey, "Three-color subtractive photography," *Jour. SMPE*, vol. 52, pp. 119–132, Feb. 1949.
7. Karl Schinzel and Ludwig Schinzel, "Copies from Monopack Negatives," *Das Lichtbild*, vol. 12, p. 137, 1937. (Translated by Joseph S. Friedman, *Amer. Photography*, vol. 32, p. 439, June 1938.)
8. A. B. Klein, "Color cinematography," Chapman & Hall, London, 1939, p. 438.
9. O. K. Kendall, "16-mm film color compensation," *Jour. SMPTE*, vol. 54, pp. 464–479, Apr. 1950.
10. H. G. Morse, "Color film exposure and first development timing," *PSA Jour.*, Sec. B., No. 1, vol. 17, pp. 2–6, Feb. 1951.
11. F. C. Williams, "Current problems in the sensitometry of color materials and processes," *Jour. SMPTE*, vol. 56, pp. 1–12, Jan. 1951.
12. J. E. Bates and I. V. Runyan, "Processing control procedures for Ansco Color film," *Jour. SMPE*, vol. 53, pp. 3–24, July 1949.

Proposed American Standard

Almost from the outset of the motion picture industry, the size and shape of the 35-mm film perforation presented a continuous and continuing problem. The Proposed American Standard appearing on the following pages is another attempt to standardize a single perforation (Dubray-Howell) for both negative and positive film. However, this is not offered now as a universal perforation to replace the two separate standards but rather as a third and *alternate* cutting and perforating standard. It is again published here for 90-day trial and criticism. All comments should be sent to Henry Kogel, SMPTE Staff Engineer, prior to January 1952 along with a carbon for Dr. E. K. Carver, Chairman of the Film Dimensions Committee.

This proposal and a detailed history of the subject were previously published in April 1949; however, objections were raised and the proposal was rejected by the Standards Committee on the grounds that a 90-day trial period was insufficient for a proposal of this nature. It has since been thrashed out in meetings of the Film Dimensions Committee, changes of a non-dimensional character made, and all objections overcome. Since a period of well over two years has elapsed, it is believed that a 90-day period, subsequent to this publication, should be adequate for comment.

A brief review of the sprocket-hole story is provided for background information.

The first attempt at standardization was initiated with a paper by D. J. Bell, published in the Journal for October 1916. He proposed a perforation having a width of 0.110 in., a height of 0.073 in. and rounded sides. Within a few years, this "Bell & Howell" perforation was accepted almost universally and was formally standardized in 1922. This development led in turn to a redesign of sprocket teeth to provide a greater picture steadiness with the accepted perforation.

However, after some time, it was noted that this perforation gave evidence of fracturing at the corners when run frequently through projection equipment. In 1923, (on the basis of experimental tests) J. G. Jones proposed a rectangular perforation having filleted corners, the same 0.110-in. width and an increased height, 0.078 in., to eliminate sprocket-tooth interference encountered previously with the 0.073-in. dimension. Since this new perforation might have given trouble in some cameras then in use, its use was not recommended for negative films. With its adoption in October 1925, separate standards for positive and negative film came into existence.

The present proposal was first put forth by Messrs. Dubray and Howell in April 1932. They claimed that it combined the advantages of both perforations and that film so perforated could still be used on all existing equipment without alteration. This, however, found few supporters at the time and instead the existing rectangular perforation for positive film was adopted in 1933 as the universal standard for both negative and positive film. Although this standard was used for positive and sound film, it was not used for camera negative film.

In 1937 the Subcommittee on Film Perforating Standards proposed withdrawal of the 1933 standard and adoption of the Dubray-Howell proposal in its place—but without success.

It then became apparent that establishing a universal perforation would be very difficult. This left negative film without an official standard and consequently the old Bell & Howell perforation, still in common use, was re-established as a standard for negative film.

The issue lay dormant until some time in 1945 when the American Standards Association asked the Society of Motion Picture Engineers to reaffirm or revise the standards, in accordance with its policy of periodic review of all standards. In the reviewing process the Motion Picture Research Council refused to approve the negative perforating standard and instead proposed that the whole question be reinvestigated and the Dubray-Howell perforation be reconsidered. The Film Dimensions Committee, therefore, initiated and carried through a rather thorough study of the whole question during 1947–48. The study revealed that this perforation had a projection life superior to the negative perforation and only slightly less than the positive perforation. In addition, it operated satisfactorily in most equipment designed for either of the old perforations and also produced films of satisfactory steadiness. (For additional information on the studies of the Dubray-Howell perforations made by the Motion Picture Research Council, see the January 1951 *Journal*, p. 30.)

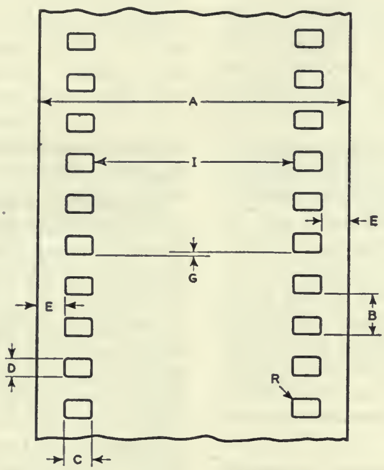
At about this time, the registration problem that exists in the printing of certain types of color release prints enters the picture. It is possible to solve the problem by the use of cine negative perforations in the release prints, but then shortened projection life becomes a factor. Meanwhile, two producers used film having the Dubray-Howell perforation for a number of color release prints and obtained very satisfactory results when printing from standard negative Bell & Howell perforations. This lent added weight and significance to the attempts to standardize the Dubray-Howell perforation and, indeed, was the stated reason for the publication of this standard initially in April 1949.

In December 1949 Ansco proposed another type of perforation which they believed might be superior to the Dubray-Howell. This is essentially the negative perforation but with fillets in the previously sharp corners to provide additional strength. The Film Dimensions Committee agreed to wait six to eight months while Ansco conducted their tests and to then review all the experimental evidence. This was done at a subsequent meeting in October 1950. The comparison of the Dubray-Howell and "modified negative" showed little difference as to camera steadiness but definite superiority with the latter in printing. The tests on projection life were not complete but in all cases the modified negative was never worse than the Dubray-Howell. (For a more complete history on the Ansco proposal see the W. G. Hill paper in the August 1951 *Journal*, p. 108.)

The Film Dimensions Committee recommends preliminary publication of the Dubray-Howell proposal at this time, under the belief that: (1) it is not advisable to delay action until final proof is at hand as to the best type of perforation. and (2) the present wide use of the Dubray-Howell perforation means that it is probably here to stay for some time. The proposal is labelled "an alternate standard" in view of the continued usefulness of the present standards and the possibility of a fourth standard becoming the ultimate universal single standard.

Proposed American Standard **Cutting and Perforating Dimensions for 35-Mm Motion Picture Film - Alternate Standards for Either Positive or Negative Raw Stock**	**PH 22.1**

P. 1 of 2 pp.



Dimensions	Inches	Millimeters
A	1.377 ± 0.001	34.980 ± 0.025
B	0.1870 ± 0.0005	4.750 ± 0.013
C	0.1100 ± 0.0004	2.794 ± 0.01
D	0.0730 ± 0.0004	1.85 ± 0.01
E	0.079 ± 0.002	2.01 ± 0.05
G	Not > 0.001	Not > 0.025
I	0.999 ± 0.002	25.37 ± 0.05
L*	18.700 ± 0.015	474.98 ± 0.38
R	0.013 ± 0.001	0.330 ± 0.025

These dimensions and tolerances apply to the material immediately after cutting and perforating.

* This dimension represents the length of any 100 consecutive perforation intervals.

NOT APPROVED

Proposed American Standard

Cutting and Perforating Dimensions for 35-Mm Motion Picture Film - Alternate Standards for Either Positive or Negative Raw Stock

PH 22.1

Appendix

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important.

Perforations of this size and shape were first described in the Journal of the SMPE in 1932 by Dubray and Howell. In 1937, a subcommittee report reviewed the work to date. The main interest in the perforation at that time was in its use as a universal perforation for both positive and negative film. The perforation has been adopted as a standard at this time largely because it has a projection life comparable to that of the perforation used for ordinary cine positive film (Z22.36–1947), and the same over-all dimensions as the perforations used in the negative film (Z22.34–1949). It should be particularly noted that although the present standard has the same over-all dimensions as the older cine negative perforation, positioning pins or sprocket teeth made to fit this perforation exactly will injure the corners of the cine negative perforation.

NOT APPROVED

Engineering Activities

PH22

A meeting of ASA Sectional Committee PH22, chaired by J. A. Maurer, was held May 2, 1951. The Chairman noted that for the last several years the function of PH22 has been primarily one of formally validating proposed standards already thoroughly reviewed by several SMPTE Committees. However, the forthcoming meeting of the International Organization for Standardization (ISO) in the United States sometime during the summer of 1952 requires that PH22 play a more fundamental role.

ISO's Technical Committee 36 on Cinematography (ISO/TC 36) was formed in 1948 for the purpose of preparing world standards in the field of cinematography. The secretariat for this Committee is assigned to the ASA, which means, in effect, that PH22 is given the responsibility for technical developments leading to world standards in this field. However, outside of a limited exchange of correspondence, no formal action has been taken and no formal meeting of ISO/TC 36 has ever been held.

It has been suggested that a first meeting of ISO/TC 36 should be held in the United States some time during the summer of 1952—probably in New York City. The technical responsibility for formulating an agenda for this meeting belongs to PH22, and since this agenda must be determined six months in advance of the meeting date, negotiations leading to its determination must be concluded by the end of this year. In order to get things started, Mr. Maurer advised that he, in cooperation with SMPTE Engineering Vice-President F. T. Bowditch, had reviewed all current American Standards and recent proposed standards, and that these had been referred to the appropriate SMPTE Engineering Committees and to the Motion Picture Research Council with the request that a definite recommendation with respect to international standardization be submitted in each case, together with reasons for such recommendations.

In the discussion the question was raised as to whether the agenda for this first meeting should include all possible standards or only the most important ones. It was finally agreed that the agenda should be confined to the most essential matters, leaving simply as "not proposed" those present standards considered either not suitable or not important.

As a matter of procedure in defining the agenda, it was agreed that a formal letter ballot of the entire PH22 Committee is not required. When the SMPTE notifies the Chairman of PH22 that a group of standards has been considered suitable for consideration as world standards, he will send out a letter notifying the members of PH22 of this recommendation, giving a limited period of, say, two weeks during which any member may register any objections he may have.

In addition to the discussion on ISO/TC 36, a limited discussion took place on the procedure for review of foreign draft standards. The newly defined scope of PH22, was endorsed by the Committee as read.

Optics

The Optics Committee met on May 3, 1951, under the Chairmanship of R. Kingslake. Two subjects were discussed at this meeting: (a) the Proposed Standard for Lens Aperture Calibration and (b) the general problem of standards for 8-mm, 16-mm and 35-mm projection lenses.

The lens aperture calibration proposal was discussed in detail and a new draft drawn up. (This proposal will appear in the October 1951 *Journal.*)

The only current standard for projection lenses is the standard for the mount of a projection lens for 16-mm projectors using a 2.062-in. barrel, established by Committee Z52 during the war and reprinted in JAN-P-49. This lacks a few detailed specifications and will be redrawn by the Optics Committee. The Committee agreed that similar specifications should be set up for home 8-mm and 16-mm projectors. Dr. Pestrecov and Mr. Maulbetsch were asked to draw up similar outline limitations for two sizes of 35-mm

projection lenses. These will then be sent to all projector and lens manufacturers for comment.

Film Projection Practice

This Committee held its first meeting under its new Chairman, M. D. O'Brien, on May 3, 1951. Past activity and inactivity were discussed and plans made for future action. Specific issues tackled were:

1. Projection-Room Plans. This is to be reviewed and revised by a task group of three and prepared for *Journal* publication.

2. Projection-Room Maintenance Instructions. The advisability of this project was questioned and the Chairman is to give it further study.

3. Lamp-Mounting Dimensions. The need for standardization was emphasized and a survey on existing equipment proposed. Mr. Davee accepted responsibility for the initial phase of this project.

4. Review of Standards. Two Standards, PH22.28 and PH22.58, were studied as potential International Standards but rejected on the grounds that they required revision. Messrs. Schlanger and Todd agreed to draw up a new draft of PH22.28. The Committee did not wish to overextend its initial activity and, therefore, relegated revision of PH22.58 for future action. Review of PH22.4 was on the agenda but was also tabled for future consideration.

Films for Television Committee

The emulsion position of 16-mm film (toward screen or lens) has been a vexing problem for some time and it was again reviewed at the May 2, 1951, meeting of this Committee. Dr. Garman, the Chairman, stated that he had received a good deal of correspondence on this question and that it might be helpful if someone would abstract the gist of the comments. Mr. Schlafly offered to do this and Messrs. Dewhirst, Misener and Veal proferred additional information to help round out the picture. (A symposium on this topic is to be held at the Society's 70th Convention in Hollywood, October 15–18.)

The new "Society Leader" was also discussed, the Subcommittee chaired by C. L. Townsend having asked the parent Committee for authorization to publish a status report. After making minor amendments, the Committee gave its approval for *Journal* publication. (The report was published in the May 1951 *Journal.*)

In addition, a new Subcommittee was formed, chaired by W. F. Little, dealing with the many problems relating to pictorial quality of television films. The Subcommittee's scope will also include preparation of a glossary of terms peculiar to the subject material studied and a continued consideration of the 30-frame question.—HK.

Atlantic Coast Meeting on Animation

At the March meeting of the Atlantic Coast Section of the SMPTE, Paul Terry of Terrytoons, New Rochelle, N.Y., showed a film describing the making of animated cartoons at his studios and then showed a couple of cartoons that had been featured in the "how-to." Mr. Terry himself supplied the narration. A brief history of animation was presented with appropriate pictures and illustrations.

Since the dawn of man, the artist has been intrigued with the idea of achieving not only a fine record of life and events in a work of art, but also actual records of scenes in motion. The photographer attained motion when the motion picture camera was perfected, but the draughtsman had the difficult handicap of attempting to record a drawing so that it appeared to be an actual movement.

The Stone Age genius who drew the Wild Boar of Altamira in Spain 20,000 years ago, suggested the motion of a running beast by drawing wiggly lines by its legs, exactly as the comic-strip artist renders it today. This represents, perhaps, the very first suggestion of animation. The Egyptian Goddess Isis was painted on each of 110 columns on a temple in 1600 B.C. Each figure was in a progressively changed position so that a dashing charioteer passing by enjoyed an illustion of motion, with these

110 images merging into one dancing figure. The ancient Greeks and Chinese also did much the same thing on vases and scrolls.

Others, including the versatile Leonardo da Vinci, rendered different positions of the human figure, in which several drawings were superimposed on one space, suggesting animation.

Perhaps the first conscious attempt at comical drawings suggesting motion was by a German named Athanasius Kircher who devised the first magic lantern and did two drawings of a mouse crawling into a sleeping man's mouth. This was done in two projections of still drawings, like a comic strip, in 1640.

In 1824, Peter Mark Roget discovered a vital principle of sight. He learned that the eye tends to retain an image it has just seen. If this were not so, motion pictures would be impossible. He built a spinning top that had a bird on one side and a cage on the other. When the top spun, the bird seemed to be in the cage.

William Lincoln patented a device called the Zoetrope in 1867, and this marked the introduction of animated cartoons into this country. It consisted of a wide shallow cylinder, mounted on a stand. The cylinder had a number of spaced slits near the tops and the drawings, made on a strip of paper about two and a half feet long, were inserted on the inside of the cylinder. As the cylinder revolved, one would look through the moving slits and there would be a sense of motion of the slightly different drawings on the strip.

There were many pioneers who struggled, often in vain, to perfect better devices for animation. One even lost his sight as a result of such a striving, and the world is deeply indebted to these great persistent men.

The common "flipper book" was introduced in 1868. It was made up of a pad of drawings bound in book fashion along one edge. The book was held in one hand, along the bound edge, while the other hand flipped the pages. As they slipped from under the thumb, the drawings, all in sequence, passed quickly before the eyes and gave the illusion of continuous motion—the animated cartoon.

The first experimental cartoon was created by a newspaper artist named James Stuart Blocton, encouraged by Thomas A. Edison. He made 3000 drawings of funny faces and jugglers and called it "Humorous Phases of Funny Faces." It was exhibited to the public, which found it hilarious fare in 1906.

To Winsor McCay, another newspaper artist, goes credit for the animated cartoon in the form in which it appears today. In 1909, he made *Gertie, the Dinosaur*, the first complete story-depicting animated cartoon. In all, McCay made ten cartoons, and the work that went into each cartoon was staggering. He drew all the thousands of pictures complete with background scenes in each.

Paul Terry pays the greatest tribute to McCay, not only as the man who inspired him to start his own animated cartoon productions, but as the artist whose knowledge, ability and vision foresaw its tremendous possibilities.

In 1915, Paul Terry, then a newspaper cartoonist, developed the first process for making one background for a scene and doing the animations on celluloid and superimposing them on the backgrounds, thus vastly reducing the labor. In that year, Mr. Terry patented the first double-exposure process. At present he turns out 26 two-reel features a year at his New Rochelle plant.

The development of both music and story ideas which go into Terrytoons was shown in color movies of Mr. Terry's 80-man staff at work. Music and sound-strip come first, even as in *Tales of Hoffman*, then story and pictures are tailored to fit. Rapport exists between composers and writers, however, and the composers do the score with a certain story line in mind. If Mighty Mouse is to kiss his lady, the length of time is estimated before the composer sits down at the piano. A good many motions are rehearsed and clocked on a metronome in these precomposition conferences, and Mr. Terry assured his audience that even a bull being tossed out of an arena can be "seen" and timed by the conferees. This throwing of the bull, however, does not impede production.

In addition to the above report, which was kindly checked by Mr. Terry, we have been able to get the following reference list from Ernest M. Pittaro.

A Reference List on Animation

SMPE Journal Articles

J. A. Norling, "Trick and process cinematography," *Jour. SMPE*, vol. 28, pp. 136–157, Feb. 1937.

J. E. Burks, "A third-dimensional effect in animated cartoons," *Jour. SMPE*, vol. 28, pp. 39–42, Jan. 1937.

E. Theisen, "The history of the animated cartoon," *Jour. SMPE*, vol. 21, pp. 239–249, Sept. 1933.

W. Garity, "The production of animated cartoons," *Jour. SMPE*, vol. 20, pp. 309–322, Apr. 1933.

Magazine Articles

J. Noble, "History of the animated film," *Intern. Phot.*, vol. 21, Pt. I, pp. 13–16, Apr. 1949; Pt. II, pp. 13–16, May 1949.

N. Taylor, "Animated movie making for the beginner," *Home Movies*, Aug. 1946.

H. Black, "Lucite and Lantz came through for the Navy," *Am. Cinemat.*, vol. 26, pp. 372–373, 392, Nov. 1945.

W. Bosco, "Harman unveils new animation unit," *Am. Cinemat.*, vol. 26, pp. 190–191, June, 1945.

A. Wolff, "Simple cartoons," *Movie Makers*, vol. 18, pp. 472, 492–493, Dec. 1943.

C. Randall, "Animation for amateur defense films," *Home Movies*, vol. 9, pp. 185, 206–207, May 1942.

C. Fallberg, "Animated cartoon production today," *Am. Cinemat.*, vol. 23: Pt. I, pp. 151, 188–190, Apr. 1942; Pt. II, pp. 202–203, 232–237, May 1942; Pt. III, pp. 250–251, 282–285, June 1942; Pt. IV, pp. 300–303, 331–332, July 1942; Pt. V, pp. 344–346, 380–382, Aug. 1942.

M. Goldberger, "Making maps move," *Movie Makers*, vol. 11, pp. 479, 489–490, Nov. 1936.

W. Lantz, "Synchronizing sound cartoons," *Am. Cinemat.*, (*Amateur Movie Section*) vol. 16, pp. 76, 82–83, Feb. 1935.

H. Angell, "Animation Advice," *Movie Makers*, vol. 8, pp. 152–153, 170, Apr. 1933.

W. Lantz, "Sound cartoons and 16-mm," *Am. Cinemat.*, vol. 13, pp. 36–37, 41, July 1932.

Books

Raymond Spottiswoode, *Film and Its Techniques*, University of California Press, Los Angeles, 1951, pp. 120–146.

W. Foster, *Animated Cartoons*, Foster Art Service, Inc., Laguna Beach, Calif., 36 pps. Very little text, all drawings and charts for those interested in the drawing phase of animated cartoons. This is an excellent treatment of modern animated cartoon technique.

P. Blair, *Advanced Animation*, Foster Art Service, Inc., Laguna Beach, Calif. This again treats the drawing and cartooning aspect of animation. It is an excellent reference and in constant use by professional animators in the industry but of interest to those looking for information about the drawing of animated cartoons, not their production from a technical standpoint.

J. Battison, *Movies for TV*, Macmillan, New York, 1950. One chapter in which animation comes in for a light lay treatment.

H. Gipson, *Films in Business and Industry*, McGraw-Hill, New York, 1947, 291 pps. Several mentions and many reproductions of various types of animation with chapter on animation. Well worth reading.

A. Epstein, *How to Draw Animated Cartoons*, Greenberg Publishers, 201 E. 57th St., New York, 1945, 64 pp. A superficial treatment of animation from the drawing standpoint.

R. Field, *The Art of Walt Disney*, Macmillan, New York, 1942, 290 pps. Written from the lay viewpoint. Of interest from the drawing standpoint, containing many excellent reproductions of Disney cartoons.

N. Falk, *How to Make Animated Cartoons*, Foundation Books, New York, 1941, 79 pps. A nontechnical treatise of interest to the layman.

E. Lutz, *The Motion Picture Cameraman*, Scribners, New York, 1927, 248 pps. This book is outdated, but has a chapter with interesting information relative to animation.

E. Lutz, *Animated Cartoons*, Scribners, New York, 1926, 261 pps. Although outdated, this book contains some valuable information.

If readers know of additional sources of information about animation, correspondence will be welcomed by Ernest M. Pittaro, 137-65 70th Ave., Flushing, N.Y.

International Commission on Illumination

Among the organizations in which our Society maintains official representation is the United States National Committee of the International Commission on Illumination.

Present SMPTE representatives to the USNC whose terms continue until December 31, 1952, are: Herbert Barnett, General Precision Laboratory; R. E. Farnham, General Electric Co.; and H. E. White, Eastman Kodak Co.

The ICI has these objectives:

1. to provide an International forum for all matters relating to the science and art of illumination;
2. to promote by all appropriate means the study of such matters;
3. to provide for the interchange of information between the different countries; and
4. to agree upon and to publish international recommendations.

"While owing its chief allegiance to this country, the United States National Committee desires to cooperate fully and cordially with the ICI and its other national committees for the promotion of the science and art of illumination and for the establishment of cordial international relations. It is important that those who act for the Committee keep these objectives fully in mind, and diplomatically extend friendly helping hands to other countries without permitting American ideals to be sacrificed or ignored."

During Session XII of the ICI held in Stockholm, Sweden, June 26 to July 7, 1951, Dr. Ward Harrison of the United States was elected president of the Commission for a term ending in 1955.

C. A. Atherton of the United States, long a delegate to the ICI, was elected Honorary Secretary. A paper prepared by Ralph Evans (Eastman Kodak Co.) was presented by Dr. Dean B. Judd of the National Bureau of Standards, because Ralph was unable to attend.

Numerous items on the agenda of Session XII include such matters as definitions of fundamental terms used in the field of illumination and photometry, and standards of luminous intensity and luminous flux. Scotopic luminosity functions for young eyes were discussed and relative luminosity values to be used in determining threshold response were set down at length. In addition, attention was given to such practical matters as highway lighting and automobile headlights. Of particular interest to Society members were the recommendations presented on the subject of theater screen lighting and television. These are quoted in their entirety:

Committee 62d, Screen Lighting in Cinemas

"*1. Screen brightness.* When showing 35-mm film it is recommended that the brightness measured in the middle of the screen shall be 35 (+15–10) nit. Whilst the measurements are being taken, the projector is to be running without film. The arc lamp current desired shall be accurately set, and the arc lamp shall be adjusted to give maximum lighting in the middle of the screen. In the middle of the short side of the screen the brightness must not be below 75% of the value in the middle of the screen.

"2. It is further recommended that the Secretariat Committee shall study the question of desirable brightness values for screens less than 3 m or more than 8 m wide.

"*3. Stray light.* The Cinema Lighting Committee draws attention to the French experiments indicating that the screen brightness, due to stray light (measured with the projector running) should not exceed 5% of the value obtained with the projector operating without film in it, and recommends that National Committees should make similar experiments.

"*4. Brightness of Surround.* It is recommended that each country report at the next meeting, information of brightness screen surround, preferably including screen brightness values as well."

Committee 63, Television

"1. It is desirable that each interested country, prior to the next session, should propose a report covering lighting developments in the field of black-and-white television (lighting of the studios and for reception).

"*2.* It is suggested that a special subcommittee be appointed to deal with color television.

"*3.* It is desirable to collect information dealing with the ambient lighting used when viewing.

"*4.* It is desirable to propose in collaboration with the transmission authorities, instructions for the use of televiewers, which will enable them to adjust their receivers to give the best reception.

"*5.* It is desirable that a thorough study should be made with the object of improving the quality of films used in television.

"*6.* It is desirable that a study of visual fatigue due to viewing be made in each country in collaboration with the appropriate medical body."

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY,

Honorary **(H)** Fellow **(F)** Active **(M)** Associate **(A)** Student **(S)**

Apitsch, John W., Sound Engineer, Twentieth Century-Fox Film Corp. **Mail:** 10367 Cheviot Dr., Los Angeles 64, Calif. **(A)**

Bury, John L., Jr., University of Hollywood. **Mail:** 226 Argonne Ave., Long Beach 3, Calif. **(S)**

Demoreuille, Pierre, President, The Carbone Corp. **Mail:** 10 Bowers Rd., Caldwell, N. J. **(M)**

Gramaglia, Albert A., Sound Mixer, RCA Sound Recording Div. **Mail:** 685 E. 237 St., New York 66, N.Y. **(A)**

Haburton, Ralph, Chief, Processing Branch, Motion Picture Section, U.S. Air Force, Wright-Patterson Air Force Base. **Mail:** 1335 Oakdale Ave., Dayton 10, Ohio. **(M)**

Herald, Robert L., 1306 N. Pennsylvania St., Indianapolis, Ind. **(A)**

Hurd, Yorick G., Physicist, Twentieth Century-Fox Film Corp. **Mail:** 228-35 Mentone Ave., Rosedale 10, L.I., N.Y. **(M)**

Kammerer, Guenter, Technician. **Mail:** c/o The Vines, 1208 Drummond St., Montreal, P.Q., Canada. **(A)**

Knutson, N. Theodore, New Product Designer, Bell & Howell Co. **Mail:** 5230 Oakdale Ave., Chicago 41, Ill. **(A)**

Koeber, Henry J., Jr., Design Engineer, Bell & Howell Co. **Mail:** 4144 N. Olcott, Chicago 34, Ill. **(A)**

Lakemacher, Elmer E., Machine Design Engineer, Bell & Howell Co. **Mail:** 3828 N. Kenneth Ave., Chicago 41, Ill. **(A)**

Lewis, David L., Production, 16-Mm Motion Pictures, Northrop Aircraft Co. **Mail:** 3619 Marcia Dr., Los Angeles 26, Calif. **(A)**

Lucas, Robert James, Chief Technician, Metro-Goldwyn-Mayer. **Mail:** 7 Orient St., Gladesville, Sydney, N.S.W., Australia. **(A)**

Mentz, Charles H., Television Engineer, KPIX. **Mail:** 416 Serrano Dr., San Francisco, Calif. **(A)**

Miyamoto, Toshio, Manager, Fukujiro Fukano. **Mail:** 876 Shimokomatsu-Machi, Katsushika-Ku, Tokyo, Japan. **(M)**

Mylander, Karl F., Ohio State University. **Mail:** 331 East Water St., Oak Harbor, Ohio. **(S)**

Nupnau, Arthur, Junior Design Engineer, Bell & Howell Co. **Mail:** 3916 N. Sawyer Ave., Chicago 18, Ill. **(A)**

Oliveri, Paul, Motion Picture Laboratory Technician, U.S. Army Signal Corp. **Mail:** 114-17—128th St., South Ozone Park, N.Y. **(A)**

Poulson, William R., TV Films, 16-Mm Laboratory. **Mail:** 5044 Walmar Ave., La Canada, Calif. **(A)**

Quateman, Joseph, Bell & Howell Co. **Mail:** 2533 Jackson, Evanston, Ill. **(A)**

Roos, Dirk J., Manager, Sound Division, Radio Specialties Co. **Mail:** 34480 Capitol Dr., Plymouth, Mich. **(A)**

Schwartzberg, Henri, Motion Picture Film Buyer, American Theatres Corp. **Mail:** 72 Beaconsfield Rd., Brookline 46, Mass. **(A)**

Seward, Edward, Free-lance Motion Picture Director. **Mail:** 3312—72 St., Jackson Heights, L.I., N.Y. **(M)**

Shimek, John A., Production Engineer, Bell & Howell Co., 1700 McCormick Rd., Chicago 45, Ill. **(A)**

Strang, William C., Specialist, 16-Mm Film Reports, North American Aviation, Inc. **Mail:** 4454 Lakewood Blvd., Long Beach 8, Calif. **(A)**

Thornwald, Everett D., Design Engineer, Bell & Howell Co. **Mail:** 1348½ Estes Ave., Chicago 26, Ill. **(A)**

Vinton, William H., Research Manager, Du Pont Photo Products. **Mail:** Du Pont Club, Parlin, N.J. **(M)**

Wagner, Karl L., Independent Producer. **Mail:** 501 C.C. Bk. Bldg., Des Moines 9, Iowa. **(M)**

Walker, Edwin M., Motion Picture Laboratory Technician, U.S. Air Force, Wright-Patterson Air Force Base. **Mail:** 931 Crestmore Ave., Dayton, Ohio. **(M)**

Weber, John P., Jr., Electronics Design Engineer, Bell & Howell Co. **Mail:** 6440 N. Albany, Chicago 45, Ill. **(M)**

West, John H., In charge, Film Renovating and Treating Laboratory, Rapid Film Technique. **Mail:** 3525—77th St., Jackson Heights, L.I., N.Y. **(M)**

CHANGES IN GRADE

Choudhury, Siraj-ul-Islam, Free-lance Artist, Motion Picture Production, Dept. of State and News of the Day. **Mail:** 235 Eldridge St., New York 2, N.Y. **(S)** to **(A)**

Townsend, Charles L., TV Technical Film Director, National Broadcasting Co. **Mail:** 49 Hillcrest Dr., DuMont, N.J. **(A)** to **(M)**

Vosburgh, Richard V., TV Film Editor and Cameraman, Paramount TV Productions. **Mail:** 5800 Green Oak Dr., Hollywood 28, Calif. **(S)** to **(A)**

DECEASED

Ball, J. Arthur, Consulting Engineer, Color Photography. **Mail:** 12720 Highwood St., Los Angeles 49, Calif. **(F)**

Winter, Ernest A., Service Inspector, Western Electric Co., Ltd. **Mail:** 14 Hawkeshead St., Southport, Lancaster, England. **(A)**

Obituary

J. Arthur Ball died in Los Angeles on August 27 at the age of 57. In recent years he was actively engaged as a color consultant, dividing his time between Los Angeles and New York.

He was an alumnus of Massachusetts Institute of Technology and was long associated with Technicolor, as an executive of Technicolor, Inc., and with its subsidiary, Technicolor Motion Picture Corp. which manufactures the color films. He was Technical Director for Technicolor when the firm made *Becky Sharp*, which was a forerunner of a long line of color motion pictures. In 1938, Mr. Ball was given an Oscar by the Academy of Motion Picture Arts and Sciences for his contributions to color motion pictures. Many of his patents in the field of color photography were assigned to Technicolor for whom he built a camera reported to have cost $15,000 and five months time to make.

As a consultant he had served the Photo Products Dept. of E. I. du Pont de Nemours & Co. since early 1946. During this time he had assisted in the development of Du Pont's recently introduced motion picture color positive film and on other color motion picture products. He was also recently a color consultant for the Springdale Laboratories of Time, Inc., at Stamford, Conn., and for Walt Disney Productions.

Motion pictures in color depend on the engineers' knowledge of the "Principles of Color Sensitometry." A 72-page article bearing that title and prepared by the Color Sensitometry Committee appeared in the *Journal* for June 1950. Attractive reprint copies may be purchased for $1.00.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal*.

Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer

vol. 32, Apr. 1951

Under Water With the Aquaflex (p. 132) *T. Gabbani*

Editing Magnetic Sound (p. 137) *L. L. Ryder*

Ten Basic Factors of TV Film Production (p. 138) *A. L. Marble*

vol. 32, May 1951

The Westrex Magnetic Film Recording Systems (p. 182) *R. Lawton*

Hollywood Knowhow in TV Film Production (p. 184) *L. Allen*

In the Best Professional Manner (p. 186) *W. Strenge*

vol. 32, June 1951

The Kinevox Synchronous Magnetic Film Recorder (p. 224) *R. Lawton*

Station-Production of TV Motion Pictures (p. 226) *D. L. Conway*

vol. 32, July 1951

Evolution of the Viewfinder Ground Glass (p. 262) *J. V. Noble*

The Stancil-Hoffman Synchronous Magnetic Film Recorder (p. 264) *R. Lawton*

Economical TV Filming (p. 268) *J. H. Battison*

Audio Engineering

vol. 35, Aug. 1951

Efficiency of Direct-Radiator Loudspeakers (p. 13) *V. Salmon*

A New Approach to Loudspeaker Damping (p. 20) *W. Clements*

British Kinematography

vol. 17, Dec. 1950

Practical Applications of Magnetic Re-Recording—Tape and Film, Pt. I, Historical Aspects (p. 182) *K. G. Gould*

Engineering Aspects of Film Production (p. 196) *R. Howard Cricks*

vol. 18, Jan. 1951

Motion Picture Presentation (p. 4) *S. B. Swingler and R. R. E. Pulman*

Technical Objectives in Pre-Planning Production (p. 18) *K. E. Harris*

vol. 18, Feb. 1951

Economic Aspects of Studio Lighting, Pt. I, Series-Parallel Wiring of Arcs (p. 44) *C. W. Hillyer*

Back Projection in the Kinema (p. 56) *J. L. Stableford*

vol. 19, July 1951

Presidential Address (The Motion Picture Industry) (p. 13) *L. Knopp*

The Magnetic Recording and Reproducing Equipment for the Telekinema (p. 19) *G. F. Dutton*

Electronics

vol. 24, May 1951

Constructing the Tricolor Picture Tube (p. 86)

vol. 24, July 1951

Continuous Film Scanner for TV (p. 114)

vol. 24, Aug. 1951

Plans for Compatible Color Television (p. 90)

Picture Generator for Color Television (p. 116) *R. P. Burr, W. R. Stone and R. O. Noyer*

General Electric Review

vol. 54, June 1951

Spectrum Utilization in Color Television (p. 18) *R. B. Dome*

vol. 54, July 1951

Over-Age Lamps May Mar Television Reception (p. 42) *J. H. Campbell and H. E. Schultz*

Ideal Kinema

vol. 17, May 17, 1951

Projection Equipment in the Telekinema (p. 7) *R. H. Cricks*

Televised Pictures on Large Screen (p. 9)

International Projectionist

vol. 26, Apr. 1951

Honeycomb-Condenser Lamp Optics (p. 5) *A. R. Schultze*

Evaluating the Honeycomb-Condenser Lamp (p. 6) *R. A. Mitchell*

Comparative Data Anent Nitrate Safety Film (p. 13)

Theater Television via the RCA PT-100 Equipment, Pt. V, Projectionist Operating Procedure (p. 18) *RCA Service Co., Technical Products Division*

vol. 26, May 1951

The Magic of Color (p. 13) *R. A. Mitchell*

Theater Television Via the RCA PT-100 Equipment, Pt. VI, Interpretation of Image Characteristics (p. 18)

vol. 26, June 1951

Lens-Correction: What it Means (p. 5) *A. E. Murray*

GPL's New 16-Mm Sprocket Intermittent (p. 20)

vol. 26, July 1951

The Magic of Color (p. 5) *R. A. Mitchell*

Motion Picture Herald

vol. 183, Pt. 2 (Better Theatres), June 2, 1951

Changing to Faster Lenses Can Increase Screen Light (p. 31) *G. Gagliardi*

Radio & Television News

vol. 46, July 1951

Practical Sound Engineering, Pt. V, A Brief History of Early Experiments in Reproducing Sound as Compared With Modern Systems (p. 60) *H. M. Tremaine*

The Problem of Recording TV Frequencies (p. 16) *J. D. Goodell*

vol. 46, Aug. 1951

TV Pictures in Color (p. 38) *N. Chalfin*

Tele-Tech

vol. 10, June 1951

Television Films Adapt TV Techniques (p. 38) *J. H. Battison*

vol. 10, July 1951

Latest Color Television Developments (p. 28)

Your Journals bound make a valuable permanent reference. Six issues constitute a Volume and should be bound with the special contents page (supplied beginning with Vol. 56) and index furnished with each June and December issue. For details of binding see page 702 of the June 1951 *Journal.*

Journal indexes covering the thirty-four years from 1916 through 1950 may be purchased from Society Headquarters.

1916–1930 $1.25 1930–1935 $1.25 1936–1945 $2.00 1946–1950 $1.50

American Standards form the technical foundation for motion pictures around the world. All current standards were listed by subject and by number in the *Journal* Index 1946–1950. Reprint copies of this list, which includes all previous *Journal* references to each standard, are available from Society Headquarters without charge.

Complete sets of all sixty current standards in a heavy three-post binder with the index are $13.50, plus 3% sales tax for purchases within New York City, and are available from Society Headquarters. Single copies of any particular standard must be ordered from the American Standards Association, 70 East 45th St., New York 17, N.Y.

Test films are the customary tool for checking picture and sound performance in theaters, service shops, in factories and in television stations. Twenty-seven different test films in 16- and 35-mm sizes are produced by the Society and the Motion Picture Research Council. Write to Society Headquarters for a free catalog.

Meetings of Other Societies

Theatre Equipment and Supply Manufacturers' Association (in conjunction with Theatre Equipment Dealers), Oct. 11–13, Ambassador Hotel, Los Angeles, Calif.

National Electronics Conference, Seventh Annual Conference, Oct. 22–24, Edgewater Beach Hotel, Chicago. The conference is sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers, Illinois Institute of Technology, Northwestern University and the University of Illinois, with participation by the University of Wisconsin and the Society of Motion Picture and Television Engineers.

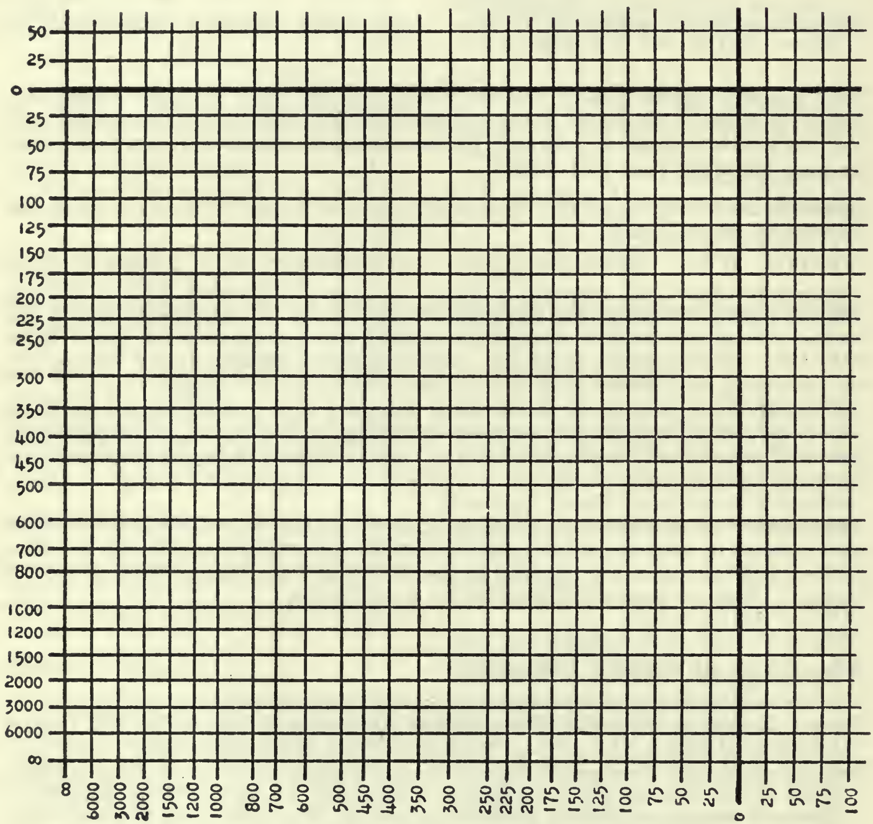
The American Institute of Physics is holding a twentieth anniversary meeting in Chicago on October 23–27. Its member societies will hold meetings at that time as follows:

- Acoustical Society of America, Oct. 23–25
- Optical Society of America, Oct. 23–25
- Society of Rheology, Oct. 24–26
- American Physical Society, Oct. 25–27
- American Association of Physics Teachers, Oct. 25–27

New Products

Further information about these items can be obtained from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.

Dylewski ARKTAN is arctangent coordinate graph paper available as $8\frac{1}{2} \times 11$ in. tracing paper at $1.00 per package of 20 sheets from Orbit Electric Co., 2710 N. Menard Ave., Chicago 39. Available at no charge are samples of the paper and a bulletin describing the paper's use for curve plotting in scientific, mathematical, engineering or statistical analysis. There are two forms: No. 1235 has one arctangent scale and one linear scale; No. 1236 (a portion of which is illustrated below) has double arctangent coordinates.



Erratum

The Utiliscope, the closed-circuit television system that was described in the July 1951 *Journal*, is made by the Diamond Power Specialty Corp. in Lancaster, *Ohio*, not in Lancaster, *Pennsylvania*, as erroneously cited in the *Journal*. This is the industrial television system that has been receiving a good deal of attention in the press because of the wide variety of applications reported, including use in motion picture production.

Electrical and Photographic Compensation in Television Film Reproduction

By P. J. HERBST, R. O. DREW and S. W. JOHNSON

THE REPRODUCTION of filmed material over the television system seldom approaches the quality of direct projection. The degradation in quality is usually apparent as loss of detail, compression in both the highlights and the shadows, increased fluctuation noise and the introduction of spurious signals in the form of shading, edge flare, spots and halo. Loss of detail and distortion of the contrast rendition can be reduced by the employment of electrical compensation. Such methods have been employed with varying degrees of success. The extent to which they can be used is limited by the aggravation of noise and spurious signals. Conventional photographic processes do not permit an increase in detail to be achieved while attempts to minimize the compression of the highlights and shadows by reducing the range of the positive transparency to be televised are accompanied by loss of resolution due to the lowered contrast in the fine detail.

Aperture Loss

The characteristics of the television system have been subjected to a comprehensive analysis by O. H. Schade.[1–4] In this analysis, the loss in resolution is considered as aperture loss and an effective scanning aperture is established for each part of the system, including both the electrical and the photographic elements. This provides a means of comparing the resolving power of such diversified factors as spot size, frequency response, bandwidth, lens sharpness and emulsion resolution.

The aperture loss in a television system is basically the same effect which occurs in the optical recording of sound on film with a slit of finite width. This effect has been thoroughly discussed by E. D. Cook[5] (in 1930). The effect may be illustrated by the simple case of a uniform rectangular aperture traveling across an area which consists of alternate black and white lines of equal width. The distortion and loss introduced by the finite dimensions of the aperture are shown in Fig. 1.

The relation of the rectangular aperture to lines of several widths is shown at (a) in this figure. The fraction of the aperture area exposed to the white lines as the aperture progresses across the image is shown at (b). In order to provide a better concept of the subjective effect, the light flux through the aperture as it passes across lines having a 10:1 contrast ratio is shown at (c). It will be seen that all detail is somewhat degraded by a subjective widening of the white lines due to the distortion of the transition edges, and

---

Presented on May 1, 1951, at the Society's Convention in New York, by P. J. Herbst, R. O. Drew and S. W. Johnson, Engineering Products Dept., RCA Victor Div., Camden 2, N. J.

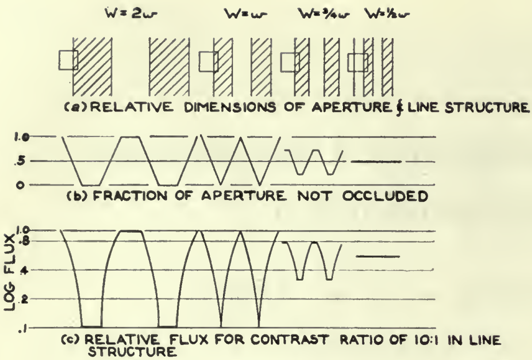


Fig. 1. Aperture flux (rectangular aperture).

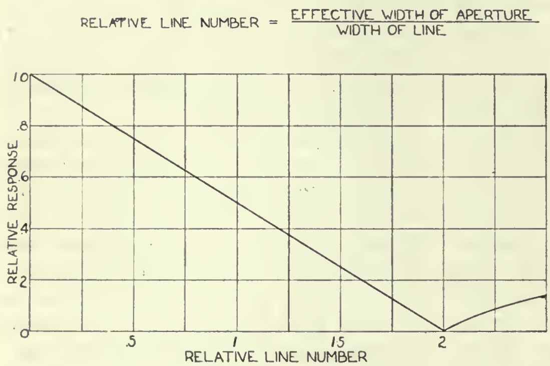
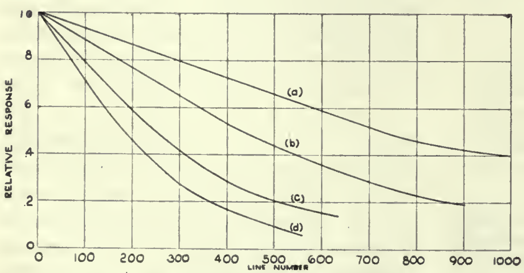


Fig. 2. Effective aperture response for square aperture.



(a) High quality experimental flying spot scanner (limiting resolution 2500 lines)
(b) Best iconoscope performance (limiting resolution 1200 lines)
(c) Image orthicon (5655) and 2-in. vidicon (limiting resolution 800 lines)
(d) Lowest iconoscope performance and 1-in. vidicon (limiting resolution 600 lines)

Fig. 3. Effective aperture response of television pickup tubes.

that the peak-to-peak ratio drops rapidly when the width of the lines becomes less than the width of the scanning aperture, reaching zero when the width of the lines is one-half that of the aperture. The relative detail contrast may be obtained by integrating the waves shown at (b) over a half-cycle. Since the eye, when viewing fine detail, integrates a portion of the transition in obtaining the sensation of maximum and minimum brightness, this method provides a measure of the apparent reduction in the ratio of the contrast between these two levels. The observed effect is the same as that produced when viewing lines of the original width but of lesser contrast. This is the equivalent square-wave response and determines the loss of detail in the system. (See Ref. 2, p. 250.)

Figure 2 shows the calculated aperture response for a rectangular aperture. The gradual loss in effective resolution is apparent in this figure.

In the television system, the effective apertures are essentially circular in shape and are not uniform in cross section. This, however, does not affect the application of this concept although the shape of the transition from black to white changes. The effective aperture response for several types of television pickup tubes is shown in Fig. 3. These curves do not include the losses of the camera lens or other parts of the television system. They represent the range of characteristics in pickup devices which may find application in televising motion picture film. A comprehensive discussion of aperture flux response factors is given by Schade.[2]

When several effective apertures are successively introduced into the system each contributes to degradation in detail. The method of computing the effective overall aperture for a number of apertures in cascade has been treated by Cawein.[6] This method is quite accurate for linear regions of the aperture response characteristics and states that the square of the effective aperture width of a number of cascaded apertures is equal to the sum of the squares of the individual aperture widths. Schade[2] applies the same process but performs the calculation in terms of the line number at which a given aperture response is obtained. In this case the square of the reciprocal of the line number of the system is equal to the sum of the squares of the reciprocals of the line numbers of the separate apertures producing the same relative response. This method has been employed to compute the effective aperture response of the system when televising 35-mm and 16-mm film. Figure 4 shows the calculated overall response including the losses introduced by the optical elements, the photographic process, a high-quality monitor and the television pickup tube. In this case a limiting resolution of 800 lines was assumed for the pickup device as representative of the performance realizable in current operations. The equivalent response of direct projected film is plotted to the same scale for comparison. In this figure the line number represents television lines, i.e., both black and white lines are counted.

Electrical Aperture Compensation

It is apparent that fine detail in the television system corresponds to high frequencies in the video signal. The aperture loss is therefore equivalent to a reduction in the amplitude response as the frequency increases. In sound reproduction such losses are frequently corrected by employing electrical networks which emphasize the higher frequencies and it appears possible to employ similar techniques in television equipment. Thus, "high-peaking" circuits are used to accentuate the higher video frequencies in both transmitting and receiving apparatus. Since this does not affect the separation between scanning lines, it is effective only in the horizontal direction and does not afford an increase in vertical detail.

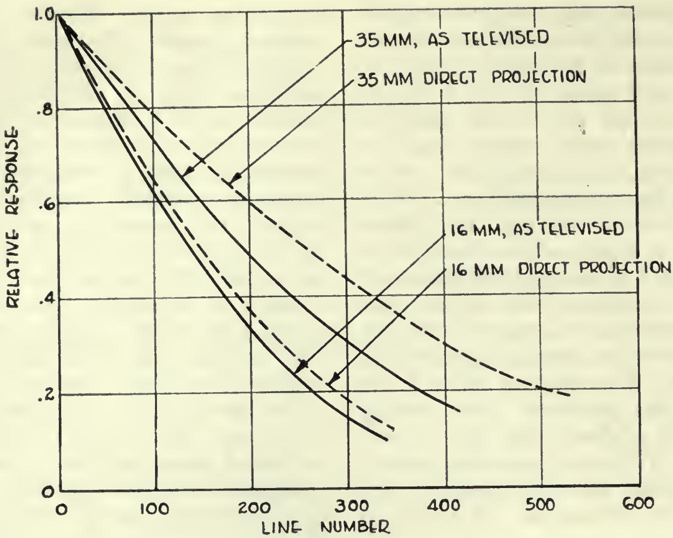


Fig. 4. Effective aperture response of television film (no compensation); limiting resolution of 800 lines assumed for pickup tubes; includes optical and photographic losses.

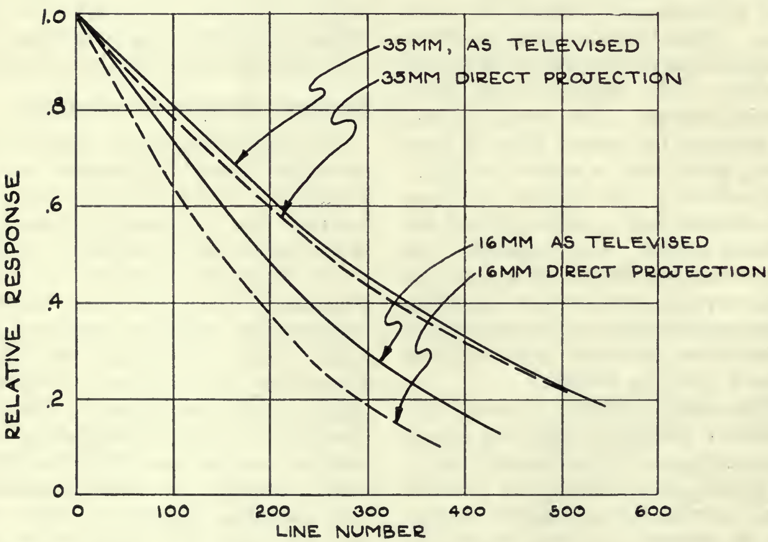


Fig. 5. Effective aperture response of television film (after compensation); limiting resolution of 800 lines assumed for pickup tubes; includes optical and photographic losses.

In a system of finite bandwidth such circuits produce transients or overshoots which appear in the image as white edges following black areas and vice versa. The effect is equivalent to the edge effects produced by some photographic processes. In the television system both the phase and the amplitude characteristics of the compensating circuit must be adjusted in order to obtain optimum compensation. When overcompensation is introduced into the system the transient effect produces an unnatural "relief" appearance which is highly objectionable. The optimum compensation which can be applied is determined by subjective effects and a complete evaluation remains to be accomplished. The effective aperture response of the television film process when the line number for a given response is increased by $\sqrt{2}$ is shown in Fig. 5. It will be noted that if this aperture correction could be employed the detail in televised film would exceed the detail obtained in direct projection. Unfortunately, the extent to which such compensation can be applied is limited by the extent to which the noise in the picture is increased.

System Noise

Noise in the signal from various pickup devices is of three types. In devices which do not employ electron multipliers the noise originates in the grid circuit of the first amplifying stage and is therefore independent of the amplitude of the video signal. The energy distribution over the video spectrum is not uniform but increases with frequency. Although this high-frequency noise is less perceptible by the eye, the application of electrical aperture compensation tends to greater accentuation of this type of noise. The iconoscope and the vidicon are both devices of this type.

The noise in the signal from image orthicons originates in the random fluctuations of the scanning beam. Since the signal is derived from a small modulation of this beam, the noise is independent of signal amplitude. It is uniformly distributed over the video spectrum and might therefore be considered as permitting more aperture compensation to be employed than in the case of amplifier limited devices. However, it has been observed that the disturbance becomes more objectionable as the frequency decreases and that the compensation required to compensate properly for aperture response usually extends into this region. The exact weight to be assigned to the subjective effect produced by different types of noise has not as yet been agreed upon. In practice the difference, as it applies to the extent to which correction can be employed, has been found negligible.

The flying spot scanner also produces noise which is uniform over the video spectrum. In this case, however, the noise originates from random emission of photoelectrons rather than from fluctuations in a comparatively large beam current. The noise amplitude is therefore proportional to the square root of the signal current. The extent to which aperture correction can be employed is limited by the same considerations as apply in the case of the image orthicon.

The actual signal-to-noise ratio will vary with the type of tube employed, the excellence of the particular unit and the conditions under which it is operated. Various measurements of camera-tube noise have been reported in the literature.[3(p.524),7] The subjective difference between "peaked" and "flat" noise prevents a precise comparison between tube types. However, qualitative differences in the degree to which corrective techniques may be applied can be obtained by employing these published figures as a basis. A fair average of the signal-to-noise in the maximum highlight signal appears to be 100:1 for the iconoscope, the vidicon and the flying spot scanner. This approximation is therefore employed in the further comparison of compensation

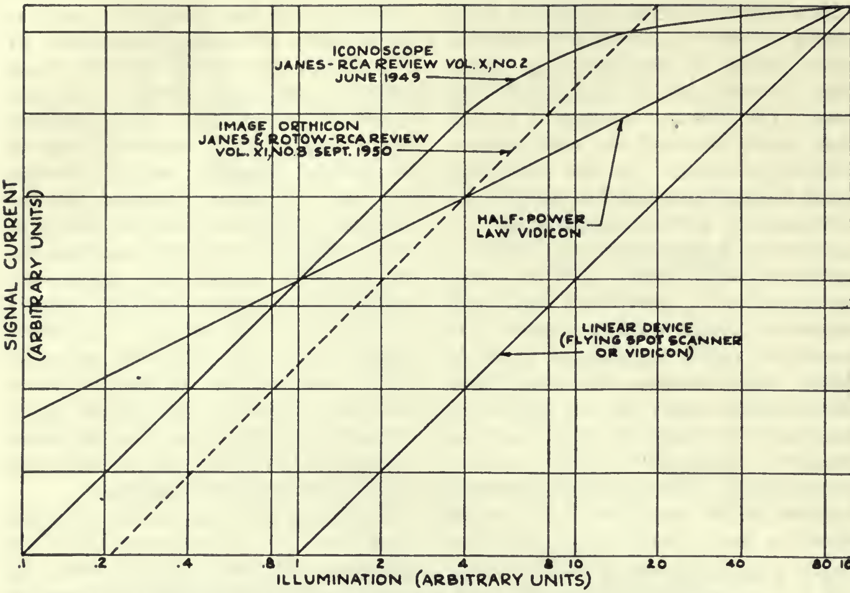


Fig. 6. Representative transfer characteristics of various types of television pickup devices.

as applied to these devices. The noise level of the present types of image orthicons is somewhat higher, especially when the tube is operated below the "knee" of its transfer characteristic. For example, the Type 5655 signal-to-noise ratio can be expected to lie between 35 and 50 to 1. Experimental image orthicons have been built in which signal-to-noise ratios exceeding 100:1 have been measured.

Transfer Characteristics of Television Pickup Tubes

Compression in both highlights and shadows in the transmission of film material over the television system is due to nonlinearity of the transfer characteristics of the camera tubes and the monitors and to the limited range which can be accommodated by the system. The transfer characteristics of several types of pickup devices are plotted in Fig. 6. The characteristic given for the iconoscope is representative of the general shape of the response curve but is subject in practice to wide departures with the average lighting and the distribution of illumination. The characteristic shown for the image orthicon is likewise merely representative since, in practice, the actual characteristic will depend upon the extent to which the highlights extend beyond the knee of the curve. The dynamic light-transfer characteristics of image orthicons has been treated by Janes and Rotow[8] and found to vary considerably with background illumination. The curve shown represents a static characteristic and seems to indicate that no contrast will be obtained in the highlights. However, the discharge of the target areas adjacent to highlights reduces the potential of these areas and provides the differential signal representative of detail. When the highlights are permitted to exceed the knee of the transfer characteristic by an appreciable amount, the redistribution effect produces objectionable halo, white objects being surrounded by black areas and detail

in light objects being almost entirely lacking. The present types of image orthicons are quite limited in the light range which they can successfully accommodate. A range of 30:1 appears to represent a practical operating limit. Under studio conditions, flat lighting and fill lights can be employed to realize this restricted range. The contrast range in most motion picture positives processed for direct projection is considerably in excess of the image orthicon capabilities. Moreover, under practical operating conditions the attention required to obtain optimum results is an objection. For these reasons the use of image orthicons of the currently available types for film pickup does not appear to be highly attractive at this time. Consideration will therefore be confined to the characteristics provided by the iconoscope, the vidicon and the flying spot scanner.

The transfer characteristic of the flying spot scanner is linear, i.e., it has a slope of unity when plotted on logarithmic coordinates. The present vidicons employed in industrial devices also have a linear transfer characteristic. A recent research being conducted at the RCA Laboratories under the direction of Dr. A. Rose makes the ultimate realization of a half-power law for the vidicon appear hopeful.

Contrast Rendition Over the Television System

In photography the contrast rendition in the final print is determined by the combined sensitometric characteristics of both negative and positive, by the maximum contrast which can be achieved, and by the flare light introduced by the printing process. The video signal from the television pickup device is modified in a similar manner by the characteristics of the video amplifier and the viewing monitor. The contribution of these various devices to the overall transfer characteristic is illustrated in Fig. 7.

In this illustration it will be noted that the viewing kinescope has a characteristic which follows a cubic response but is limited by flare light which is produced by dispersion in the phosphor and internal reflections in the glass face plate. When viewed in a darkened room a range in the order of 100:1 in screen luminance may be realized. Ambient illumination under more normal viewing conditions will result in considerable reduction in this range. It will be noted that under the best viewing conditions the range of the video signal which produces the maximum useful range of kinescope screen luminance is approximately 10:1. This depends to a large extent upon the level established for black signal. The extent of the variations has been discussed by Schade.[12]

In this diagram the transfer characteristics of the overall system have been constructed by transferring the relative signal current to the plot of the amplifier characteristic to find the relative grid signal applied to the kinescope, then transferring this to the kinescope characteristic to determine the screen luminance and plotting this value over the original point on the camera characteristic. The dotted line shows the process for one point on the characteristic obtained from an iconoscope and a linear amplifier.

This diagram shows the excessive white compression usually obtained from an uncompensated iconoscope. It also shows the extreme compression of the shadows and excessively high contrast in the remainder of the tonal range which is obtained from an uncompensated linear device. It will also be seen that the characteristic obtained with a device having a half-power law response is a fair approximation of the selected corrected response.

The amplifier characteristics required to compensate the characteristics shown at (a), (b) and (c) in Fig. 7 to the response indicated at (d) are plotted

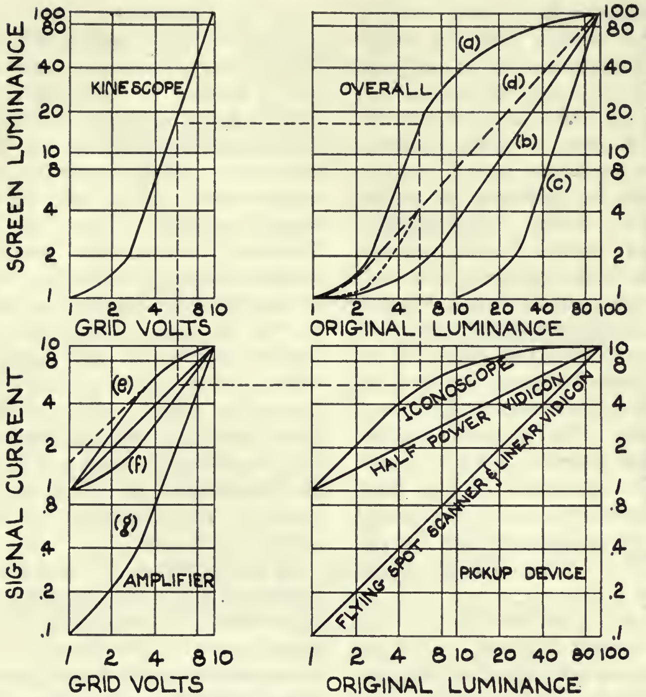


Fig. 7. Contribution of system elements to overall transfer characteristics.

(a) Overall response with iconoscope and linear amplifier
(b) Overall response with half-power law vidicon and linear amplifier
(c) Overall response with linear device (ex: flying spot scanner) and linear amplifier
(d) Overall characteristic after correction
(e) Amplifier response for correcting iconoscope characteristic
(f) Amplifier response for correcting half-power law characteristic
(g) Amplifier response for correcting characteristic of linear pickup device
NOTE: Broken parts of (d) & (e) illustrate effect of simple "white" stretching.

(All quantities in arbitrary units)

at (e), (f) and (g), respectively. In order to provide a simple method of relating the various characteristics to the overall system response the positions of the dependent and independent variables have been inverted from their usual relationships in plotting the amplifier characteristics. Partial compensation of the transfer characteristic obtained with an iconoscope has been obtained by expanding the signal in the range corresponding to the highlights. The design and performance of such amplifiers has been discussed by Goodale and Townsend.[9] When the system employs simple "white stretching," the lower portion of the amplifier characteristic is linear. The characteristic of such an amplifier is shown by the dotted departure from Curve (e). The effect is to provide better rendition of the highlights at some expense in overall range and the distortion of the characteristic in the shadows as shown by the dotted departure from Curve (d). The transfer characteristics of the compensating amplifiers are plotted on a linear scale in

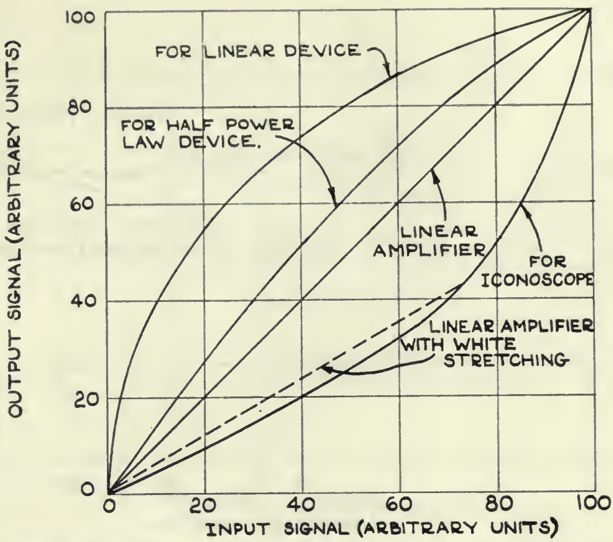


Fig. 8. Transfer characteristics of correcting amplifiers.

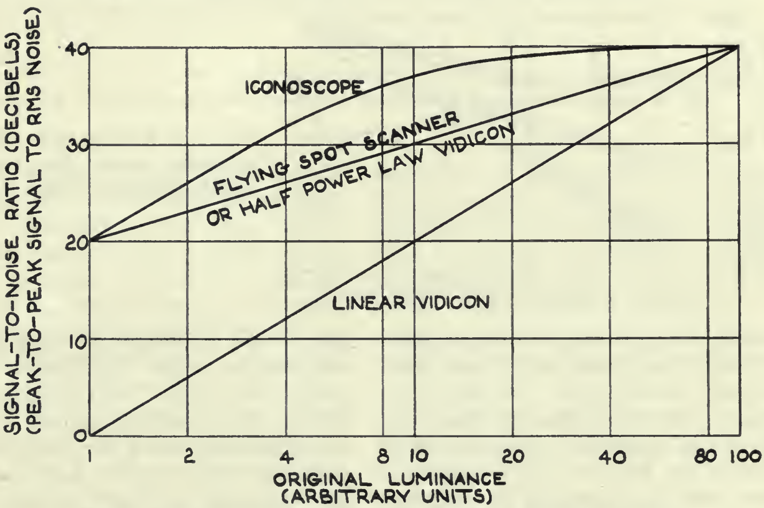


Fig. 9. Signal-to-noise ration of television pickup devices.

Fig. 8. The extent to which such compensation of the transfer characteristic can be employed again depends to a large extent upon the increase in noise level. Depending upon the luminance range in which they appear, spurious signals may also be aggravated by such compensation.

Effect of Electrical Compensation on Noise

Assuming that the various television pickup devices are capable of providing a signal-to-noise ratio of 100:1 in the highlights the fluctuation noise in the reproduced picture may be calculated

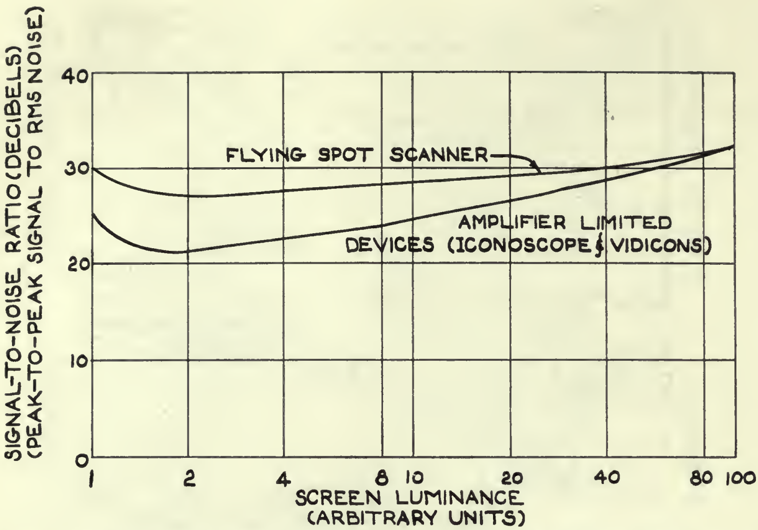


Fig. 10. Fluctuation noise in television screen (no compensation-linear amplifier).

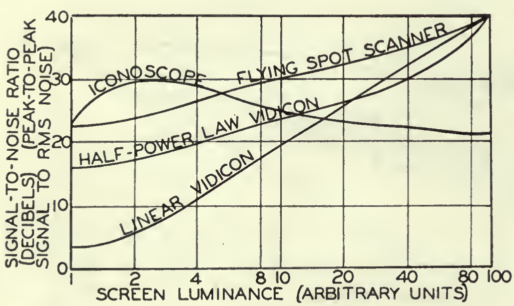


Fig. 11. Fluctuation noise in television screen after compensation of transfer characteristics.

by considering the slopes of the amplifier and monitoring kinescope at each level of screen luminance. The effect in terms of peak video signal to rms noise level in the output of the pickup devices is shown in Fig. 9. The manner in which these characteristics are modified by the transfer characteristic of the monitoring kinescope is illustrated in Fig. 10 which shows the calculated fluctuation noise plotted against kinescope screen luminance. Because the screen luminance is used as the abscissa there is no difference between the apparent noise from any of the amplitude limited devices. This is because the amplitude of the noise applied to the grid of the kinescope is constant and independent of the signal current from the pickup tube. The signal-to-noise ratio in the reproduced picture is therefore dependent upon the shape of the kinescope characteristic rather than upon the response of the camera tube employed. It will be noted that the combination of the reduced camera noise at lower signal levels and the reduced slope of the kinescope characteristic in this region result in an improved signal-to-noise ratio in the shadows. This plot does not indicate the serious distortions in contrast rendition which accompany the use of uncompensated linear devices.

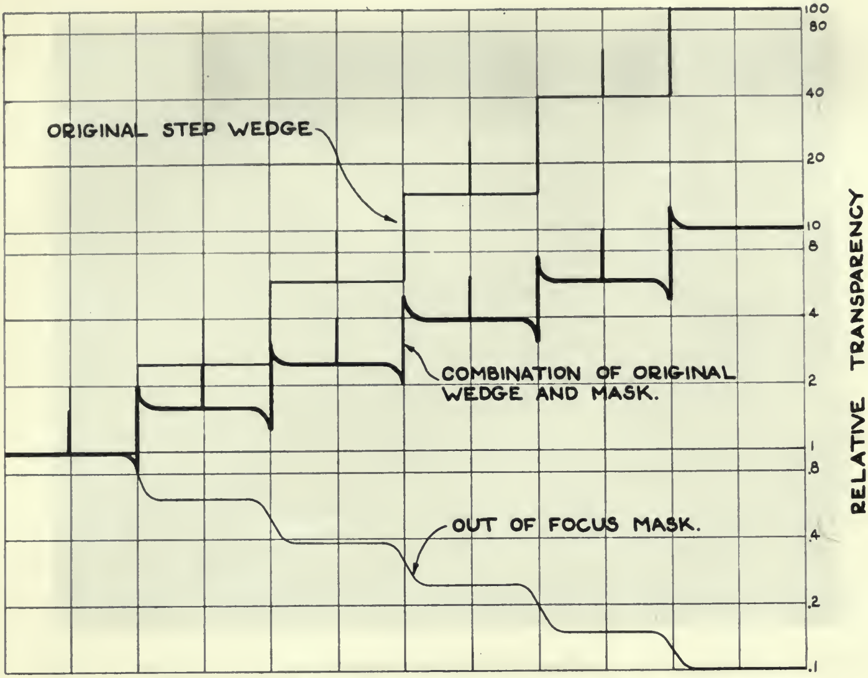


Fig. 12. Principle of area masking illustrated by detail on step wedge.

When electrical compensation for the transfer characteristic is introduced the noise is modified by the slope of the amplifier characteristic at each screen brightness level. The effect in the reproduced television image is illustrated in Fig. 11. In the case of the iconoscope the amplifier slope is reduced in the shadows and increased in the highlights. The net result is a serious increase in the noise in the highlights. The opposite is true for the other types of pickup devices all of which require expansion of the lowlight signals and compression of the signal in the highlights. The very serious increase in apparent noise in the shadows in the case of a linear device which is limited by amplifier noise is shown by the characteristic for the linear vidicon.

The subjective difference between noise in the highlights and noise in the shadows has not been considered in this discussion. Likewise, the curvature of the kinescope screen in the region of the highlights has been neglected in making these calculations. The results, however, are sufficient to indicate that the tolerance in apparent noise is insufficient to permit optimum compensation for both transfer characteristic and aperture losses to be applied without serious increase in the apparent graininess of the television image. Improvement in the signal-to-noise ratio of the pickup devices will raise the level of these noise characteristics without greatly modifying their general shape.

Photographic Area Masking

Working in a different field, G. L. Dimmick and H. E. Haynes found that the tonal range in high-contrast prints could be successfully reduced without impairment of the detail contrast and suggested that this technique, which has

Fig. 13. Original negative.

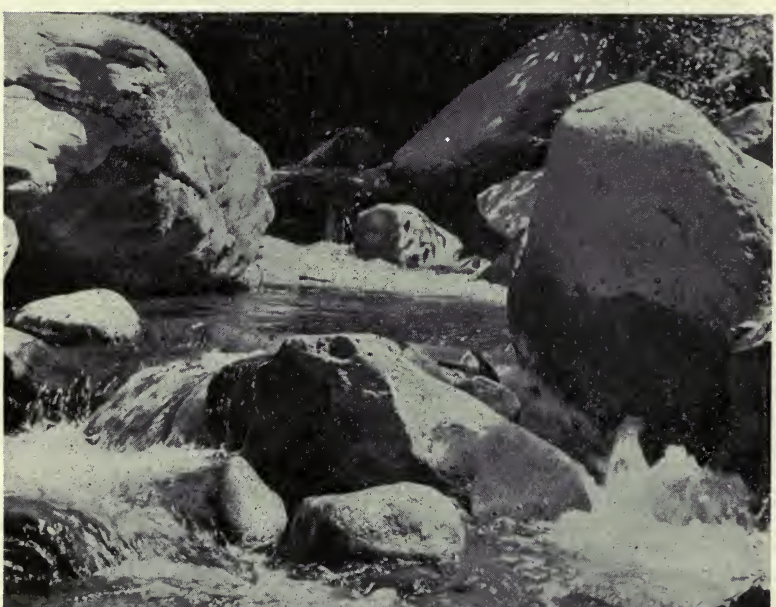


Fig. 14. Normal contrast print from negative in Fig. 13.

Fig. 15. Print processed to lower than normal contrast from negative in Fig. 13.

Fig. 16. Unsharp mask from original negative in Fig. 13.

been applied to some extent in the graphic arts, might be applied to television reproduction with equal success. A brief investigation disclosed that this photographic method could be advantageously applied to the processing of prints intended for transmission over the television system.

The technique which is known as "Area Masking" is not new since there is evidence that it was described by German experimenters as early as 1931. More recent work with unsharp masks was described by M. J. Johnson[10] in 1943, while a review of the principles and methods of obtaining the effect was published by J. A. C. Yule of Eastman Kodak Co. in 1945.[11] Recently, this method has found some application in the graphic arts where it is often necessary to reduce the wide tonal range of a picture from contrast ratios of 100:1 or greater in the properly processed transparency to a range of 20:1 or less for proper reproduction within the limitations of papers and inks. The limitations of the television system impose similar restrictions on the tonal range which can be adequately accommodated since, although the previous discussion referred to realizable ranges of 100:1 these can only be achieved under the most favorable conditions and are seldom attained in practice. A more realistic range of 30:1 seems to coincide with current informed opinion. Since motion picture positives, properly processed for direct projection, frequently contain ranges of contrast in excess of 150:1 the conditions for televised film are similar to those encountered in the reproduction of pictorial material by half-tone printing.

A mask may be considered as a photographic image which is superimposed on another photographic image to alter the characteristics of the final reproduction. If a positive transparency, processed to a low control gamma, is placed over the negative from which it was made, the contrast range is less than that in the original, and prints made from this combination on normal print stock with normal processing will contain a reduced contrast range. If the mask is in sharp focus and exact register, the net effect is that of processing the final print to a lower control gamma. However, if the image is intentionally defocused when the mask is made, the large area contrast will be reduced but the detail contrast will remain unchanged since the mask in any given area will act as a neutral filter for sharp detail, reducing the exposure of the final transparency but not affecting the detail contrast ratio. Such an unsharp mask can be made by separating the emulsion, which will constitute the mask, from the negative during exposure by a distance sufficient to produce appreciable blurring.

The principle may be illustrated by considering the effect on a step wedge having fine detail in each step. In Fig. 12 the original step wedge is considered to consist of five equal logarithmic steps covering a total overall contrast range o 100:1. The fine detail in this wedge is represented by the edges and the fine lines centered in each step. The unsharp mask is represented as having an overall contrast range of 10:1. The edges are reproduced by gradual transitions since the image is out of focus, while the fine detail in the center essentially disappears. The combination of the original transparency and the mask produces a step wedge in which the overall contrast is 10:1 while the contrast excursions at the edges and in the fine lines remain unchanged. It will be noted that in this figure the detail is shown as having a contrast excursion of one-half the contrast between successive steps in the original wedge. In the combination the detail contrast is equal to the contrast between steps while the edges are reproduced at the original contrast. This also serves to illustrate the edge effect which is produced by the process and which can result in extreme artificiality in the final transparency if the method is carried to extremes. In practice, it is

probable that the mask would be applied to the negative during the printing process. Under special circumstances the mask could be applied to the positive print when televised.

The television engineer will recognize the analogy to "high peaking" which is employed in electrical aperture compensation. The edge effects are similar to those produced by the transients or "overshoots" in electrical networks. Schade[4] has pointed out this analogy and treated the effect in some detail. Yule[11] has pointed out that this accentuation of the edges is similar to the subjective response of the eye when viewing adjacent contrasting areas and does not impair the natural appearance of the reproduced image unless excessively aggravated.

The process may be likened to automatic dodging during the printing process, each area being given the proper exposure to place it in the desired region of a reduced tonal scale. In effect, the process gives the impression of more even scene lighting while permitting natural illumination during the filming of the original scene. The method requires the production of an extra print and adds another step in the photographic process. The resultant improvement in the quality of the televised film appears to justify this additional effort.

The exact parameters to be applied during processing have not, as yet, been determined. However, the method does not appear to be critical since the very first attempts met with excellent success. The degree of defocusing which will be optimum for reproduction over the television system may be different from that which is best suited to direct viewing of an opaque print. The possible over-accentuation of detail contrast to compensate for aperture losses in the television system remains to be investigated. Because the mask is appreciably out of focus, serious registration problems are not anticipated and have not constituted a difficulty in the tests made to date. There seem to be no special difficulties in the employment of the process to obtain prints better suited to the characteristics of the system although further refinements may provide improved means of control and closer realization of optimum quality.

It will be noted that the process accomplishes the desired reduction in excessive contrast and compensation for aperture losses in one photographic step and that this is accomplished without any increase in noise except for the additional film graininess introduced by the mask. In our experiments this increase in grain has not been noticeable. The method therefore allows greater latitude for the introduction of such remaining compensation of transfer characteristic by electrical means as may be considered desirable.

Pictorial Effect of Area Masking

The effect on the picture quality can be judged from a series of reproductions made from 35-mm transparencies. It should be borne in mind that the illustrations shown here are half-tone reproductions of glossy paper prints which in turn were made from original transparencies. Transparencies demonstrate the principle of photographic area masking effectively but much information has been lost in the glossy print and half-tone processes which seriously limit the contrast range. Figure 13 is an original 35-mm normal contrast negative. A direct-contact print taken from this negative and processed for direct projection was found to have a transmission range of 130:1 (Fig. 14). This print is too contrasty to reproduce well over the television system. Figure 15 shows the effect of processing the print to lower than normal contrast. In this print, the overall contrast range was reduced to 10:1. It will be noted that the detail is lacking and the extreme flatness produces a chalky or veiled appearance.

Figure 16 shows a positive unsharp mask which when combined with the original negative produces a contrast range

Fig. 17. Area masked print from original negative in Fig. 13 and unsharp mask in Fig. 16.

Fig. 18. Photographic reproduction of the original normal contrast transparency of Fig. 14 over an iconoscope television system.

Fig. 19. Photographic reproduction of low contrast transparency of Fig. 15 over an iconocsope television system.

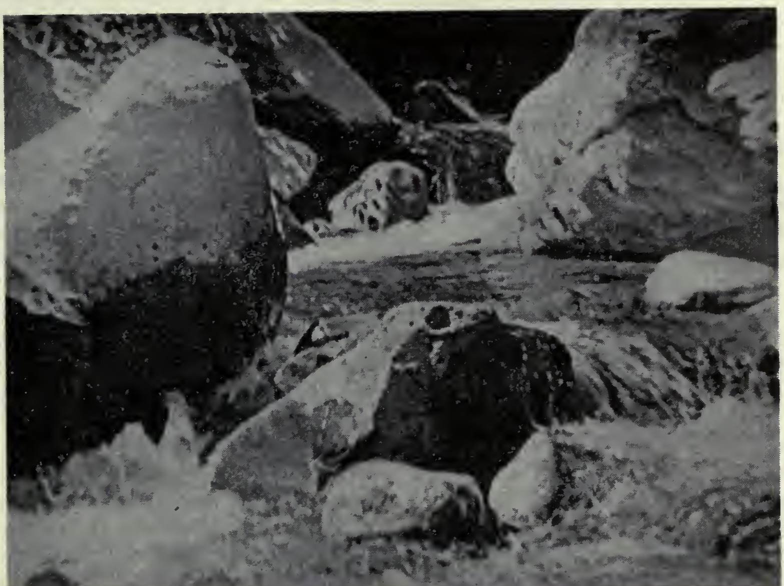


Fig. 20. Photographic reproduction of area masked transparency of Fig. 17 over an iconoscope television system.

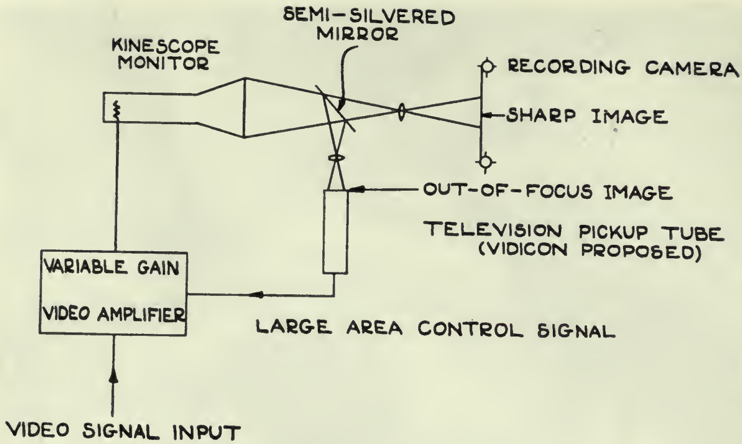


Fig. 21. Electrical area masking.

of 10:1 in a normally processed print. The print obtained by this area masking process is shown in Fig. 17. It will be noted that although the tonal range is the same as in the print made by reduction of the control gamma, the detail contrast is unimpaired. Although the appearance in direct projection is not as pleasing as the more contrasty original print, the fine detail is retained and the picture still has the quality loosely termed "snap" or "crispness."

The reproduction of the original normal contrast transparency shown in Fig. 14 over an iconoscope channel is shown in Fig. 18. This is a photograph of a 5-inch monitor having a P11 phosphor and operated over the optimum range of its characteristic. A 4 × 5-in. still camera was employed to eliminate any losses in detail by the recording process. It will be noted that both the highlights and the shadows are excessively compressed. Figure 19 is a photograph of the same monitor when the low-contrast transparency shown in Fig. 15 is televised over the same channel. The only change in the settings was to increase the gain to obtain the same video signal at the grid of the kinescope. The loss of detail is very apparent, especially in the highlights. Figure 20 is the result of televising the area masked transparency shown in Fig. 17. The good rendition of the entire tonal range and the improvement in detail are apparent.

The method, in its present state of development, has recently been demonstrated to representatives of several broadcasting companies who expressed considerable interest in its possibilities. Efforts are currently under way to apply the technique to both 16-mm and 35-mm motion picture film. It is of particular value in cases where access to the original negative is possible such as in the case of preparing advertising trailers and other material intended solely for reproduction over the television system.

It should be noted that the method is applicable to electrical circuits. One method of applying the technique to video recording is illustrated in Fig. 21. This is a block diagram showing the recording camera disposed properly in front of the kinescope monitor. By means of a semi-silvered mirror or other light-splitting device an out-of-focus image is focused on the photosensitive surface of a pickup tube. The signal from this tube represents the contrast in the large areas and is used to control the gain of an amplifying device. This circuit is equivalent in its operation to the

photographic mask. It will be noted that the gain varies with the signal level produced by the larger picture areas but is constant at any level as regards the higher-frequency signals representing the fine detail. The full advantage of the masking technique in achieving compensation without aggravating the noise is not realized in the simple circuit illustrated in Fig. 21.

Conclusion

The characteristics employed in this discussion are given as representative of the performance of several types of television pickup devices. In practice, wide variations may be observed. The actual measured figure of aperture response, transfer characteristic and signal-to-noise ratio may differ from those given since individual tubes and the conditions of operation are variable. Furthermore, further improvements in tube performance may modify any specific conclusions drawn from the foregoing.

At the present time the limitations of the television system make some form of compensation highly desirable. Unfortunately, currently available elements do not provide sufficient latitude for the incorporation of optimum electrical compensation. The principle of area masking therefore appears to offer attractive possibilities especially in the preparation of motion picture positives specifically intended for transmission over the television system.

References

1. O. H. Schade, "Electro-optical characteristics of television systems, Part I: Characteristics of vision and visual systems," *RCA Rev.*, vol. IX, no. 1, pp. 13–37, Mar. 1948.
2. O. H. Schade, "Electro-optical characteristics of television systems, Part II: Electro-optical specifications for television systems," *RCA Rev.*, vol. IX, no. 2, pp. 245–286, June 1948.
3. O. H. Schade, "Electro-optical characteristics of television systems, Part III: Electro-optical characteristics of camera systems," *RCA Rev.*, vol. IX, no. 3, pp. 490–530, Sept. 1948.
4. O. H. Schade, "Electro-optical characteristics of television systems, Part IV: Correlation and evaluation of electro-optical characteristics of imaging systems," *RCA Rev.*, vol. IX, no. 4, pp. 653–686, Dec. 1948.
5. E. D. Cook, "The aperture effect," *Jour. SMPE*, vol. 14, pp. 650–662, June 1930.
6. M. Cawein, "Television resolution as a function of line structures," *Proc. IRE*, vol. 33, pp. 855–864, Dec. 1945.
7. R. B. Janes, R. E. Johnson and R. S. Moore, "Development and performance of television camera tubes," *RCA Rev.*, vol. X, no. 2, pp. 191–223, June 1949.
8. R. B. Janes and A. A. Rotow, "Light transfer characteristics of image orthicons," *RCA Rev.*, vol. XI, no. 3, pp. 364–376, Sept. 1950.
9. C. L. Townsend and E. D. Goodale, "The orthogam amplifier," *RCA Rev.*, vol. XI, no. 3, pp. 399–410, Sept. 1950. (Abstract in *Jour. SMPTE*, vol. 56, pp. 76–78, Jan. 1951.)
10. M. V. Johnson, "Print control with blurred positive masks," *Am. Phot.*, vol. 37, pp. 14–16, Mar. 1943.
11. J. A. C. Yule, "Unsharp masks," *J. Phot. Soc. Am.*, vol. 11, no. 3, pp. 123–132, Mar. 1945.
12. O. H. Schade, "Image gradation, graininess and sharpness in television and motion picture systems, Part I: Image structure and transfer characteristics," *Jour. SMPTE*, vol. 56, pp. 137–177, Feb. 1951.

Processing 16-Mm Kodachrome Prints

By WILLIAM HEDDEN, THOMAS WEAVER and LLOYD THOMPSON

In 1949, the Eastman Kodak Company agreed to license independent laboratories to process 16-mm Kodachrome film. The first machine for this purpose has been built by The Calvin Company, and has been in use since April 1, 1950. This paper gives a description of the machine, some of the problems encountered with the process, and some of the results obtained.

When Eastman Kodak Company arranged to license independent laboratories to process 16-mm Kodachrome film, The Calvin Company decided to construct such a machine for 5265 stock. This decision was made for several reasons:

(1) It was desirable that we eliminate the necessity of sending all printed duplicates to the Chicago laboratory of Eastman Kodak Company for processing, as this caused delays even though air freight was used in both directions.

(2) The cost of shipping this material back and forth by air, and the necessary telephone calls, etc., was expensive.

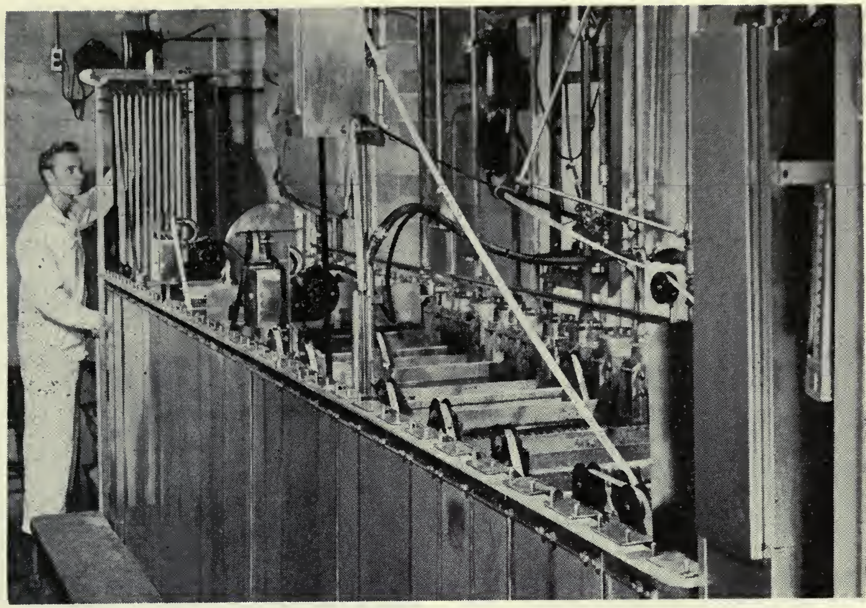
(3) It was believed that the control of processing quality within our own organization might lead to improved color quality in Kodachrome duplicates, because of closer coordination between printing and processing.

Presented on April 30, 1951, at the Society's Convention in New York, by William Hedden, Thomas Weaver and Lloyd Thompson, The Calvin Company, 1105 Truman Rd., Kansas City, Mo.

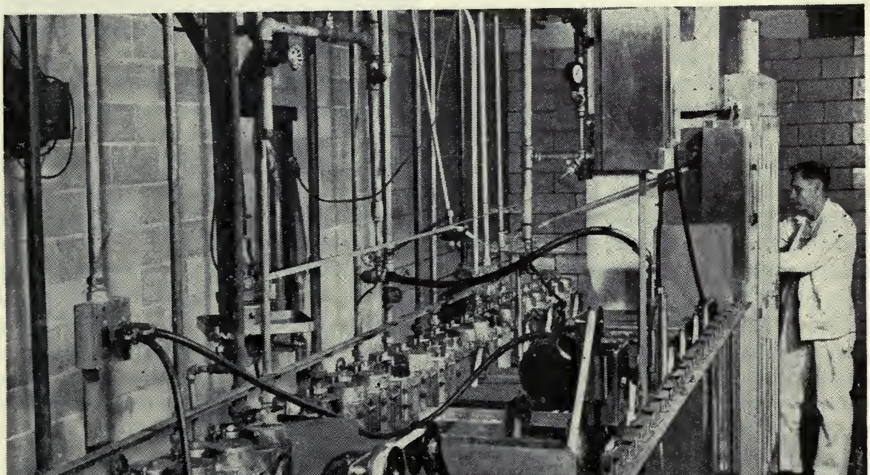
It was realized that this was a project of rather large scope. The installation would be difficult and expensive, and only a very limited amount of technical experience was available to independent laboratories. Such an installation would be somewhat different from the facilities of the Eastman laboratories, and no one could accurately predict what might happen.

The machine was planned and completed in about a year's time. Since April 1, 1950, all Kodachrome duplicates made by us have been processed in our own machine. While the basic processing information was made available by the Kodak Company in a manual for licensees, it was decided to modify the machine design.

We felt the Kodachrome machine should be built on the same basic design as our black-and-white machines, so that operators familiar with the black-and-white equipment could also run the color machine. Such a machine was easier for us to build, and certain parts were interchangeable with the black-and-



General view of Kodachrome processing machine.



Looking toward dry end of machine. In the foreground can be seen one of the color printers with the second one in about the center of the machine.

white machines. It was decided to operate our equipment at higher machine speed than the Kodak machines, in order to get additional production capacity.

After gathering as much information as possible, Bob Sutton and our Engineering Department proceeded to make a layout of a machine based on the information released by Eastman Kodak Company, and similar to our black-and-white processing machines which were originally designed following the plan of the Ansco black-and-white machine. This machine is an adaption of the modified Spohr-Thompson bottom-rack drive, and runs at 62 fpm.

Developing time of the various solutions was a factor in determining tank size, and the number of racks necessary for operation. A few extra tanks were added as a safety factor in event of a processing change. The racks and tanks were designed so that it would be comparatively easy to change tanks in order to make timing or processing solution changes.

The machine as finally constructed consists of nineteen stainless steel (type 316) tanks. The ferricyanide bleach tank is lead lined, and the rack in the bleach is made of red brass. Twenty-nine racks are used in normal operation of the process. A 2-hp, 3-phase motor supplies the power through a belt to the drive shaft. The drive shaft consists of a length of 1-in. shafting with one worm gear at each rack position enclosed in a sealed oil-filled gear case. Each worm gear drives a spur gear, and another spur gear is placed on this shaft above the gear case. When the racks are in position on the machine, the upper rack gear is meshed with the spur gear outside the gear case, and this drives the rack. Pins are used to keep the racks in proper position. Individual racks can be removed from the machine simply by lifting them out.

The bottom rollers of the drying cabinet are driven by means of a chain drive attached to the end of the main drive shaft. The drying cabinet uses a closed circuit of air in order to maintain the proper drying conditions. The humidity is controlled by the use of a Frigidaire sealed $\frac{1}{2}$-hp condensing unit. The condenser and the compressor unit are mounted in the air stream, reheating the air after it has been dehumidified by the cooling coil. This unit in conjunction with electric strip heaters, a blower and control instruments, maintains a constant relative humidity of 50% at a temperature of 85 F.

The feed cabinet at the head of the machine is large enough to permit storage of stock for almost two minutes before the elevator reaches the top.

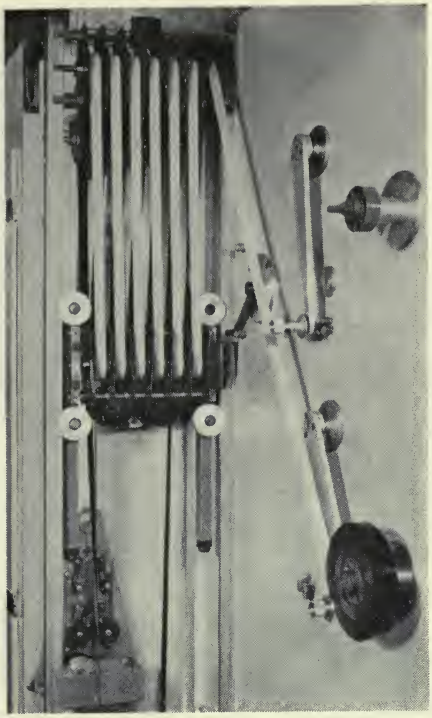
The take-off elevator is equipped with a brake which prevents rollback when take-off pressure stops. The take-off spools are driven by a torque motor to maintain constant take-up pressure. The motor has a separate operating switch so that it may be shut off momentarily while the film is being changed from one spool to another—during that time the elevator takes up the film.

The basic rack used in the machine is made of stainless steel angles, hard rubber rollers and Synthane bearings. Separators are placed between each of the 19 bottom drive rollers to prevent looping. The upper 20 rollers are fitted loosely to their shaft, and the total capacity of each rack is 126 ft.

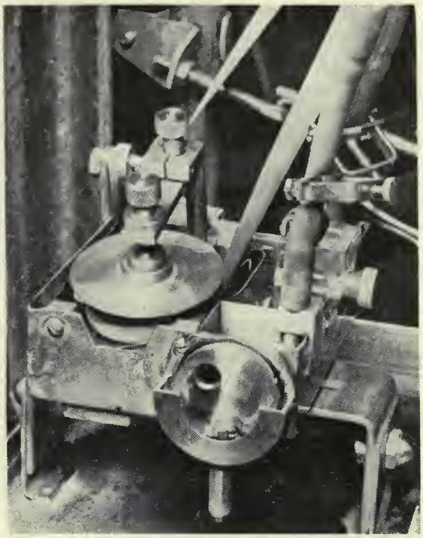
To aid in the removal of the antihalation backing of the film, buffer rollers are installed in the first three washes. A Canton flannel-covered wooden roller is suspended between the top and bottom rollers of a rack. This roller, driven by the rack drive shaft in the same direction of film travel, buffs the film base removing all the backing.

It is necessary to expose the cyan and yellow layer in the film separately before color developing; therefore, it was essential that we build a cyan and yellow printer.

In the Kodak processing machine the film runs horizontally over the printers,



Waxer, elevator and take-ups.
Take-ups are driven by torque motor.



Mechanism for applying sodium sulfide to sound-track area.

but the printer which was designed for our machine was built so that the film travels in a vertical position. Basically the printer consists of a lamp, centering light through an intergrading bar and filter, exposing the film as it travels through a masked channel. Power for the lamp is fed from transformers and adjusted by means of a Variac transformer. The intensity is measured with a foot-candle meter, and also checked by the means of an ammeter. An Aklo glass was installed in the blue printer to prevent heat from cracking the filter. Blowers are installed on each printer to carry off the heat from the lamp. An air squeegee is used before the film enters the sound applicator, and another is used just before it enters the drying cabinet. At several points throughout the machine small rubber wiper squeegees are used to prevent dilution and carryover from one tank to another.

Perhaps the most difficult processing operation to perfect was the sound track application. To develop the sound track on Kodachrome prints the film passes edgewise on an applicator wheel, while a sulfide sound developing solution is applied just to the edge area of the picture by a wiper knife blade or pen. This is done just before the magenta developing solution. After the sound developing solution has reacted a few seconds it is necessary to wash it from the film immediately to prevent any sulfide sound solution from fogging the picture area. Several methods of doing this were tried before a satisfactory system was found. The problem was finally solved by the use of vertical wash jets hitting the film at an angle, which allowed the water to flow across the track area and off the film immediately. While a manual of instructions was supplied by Eastman Kodak Company, the increased speed of our machine presented

an application problem not encountered on machines operating at lower speed. With an efficient squeegee before the sound applicator, the film was still too moist when it entered, and uneven application of the sulfide sound solution resulted. To overcome this problem it was necessary to use one of the extra tanks and racks as a dry box, which we call the "hot rack." The film is dried enough so that uniform sound application is possible. Once these problems were solved, very little trouble has been encountered with sound application.

Constant replenishment of the solutions is accomplished by the means of adding solutions controlled by stainless steel needle valves, and measured through a Stabilvis Flowrator which measures and shows the exact amount of replenisher being added at all times. This mixes with the tank solution being recirculated just before it enters the pump. It is then filtered, passed through a heat exchanger and another Flowrator which shows the rate of circulation, and then enters the system by means of a pipe at the bottom of the tank. Any excess developer which is not used overflows into the sewer by means of a pipe at the desired tank level.

A small pot made of stainless steel is placed on the system between the replenisher valve and the recirculation pump for the addition of chemicals for process correction while the system is in operation. By using this method, it is possible for the Control Department to make additions from the outside of the processing room. It also insures proper mixing and minimizes the danger of streaking film by improper handling.

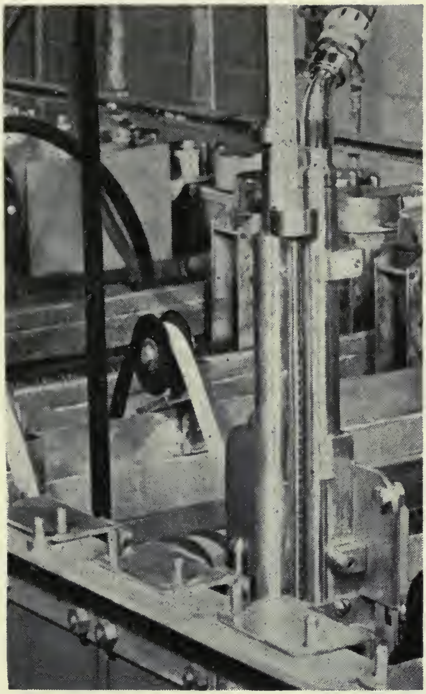
Brown temperature controls are used to maintain temperature within plus or minus one-half degree at 80 F. All solutions, including the wash water, are automatically controlled at 80 F. Automatic temperature control devices are used to mix the proper amount of cold and hot water to maintain the temperature of solution and wash water.

The amount of wash water being used in each tank is also accurately controlled, and measured by Flowrators. All the developer solutions are recirculated and filtered with the exception of the prehardener, ferricyanide bleach, and hypo.

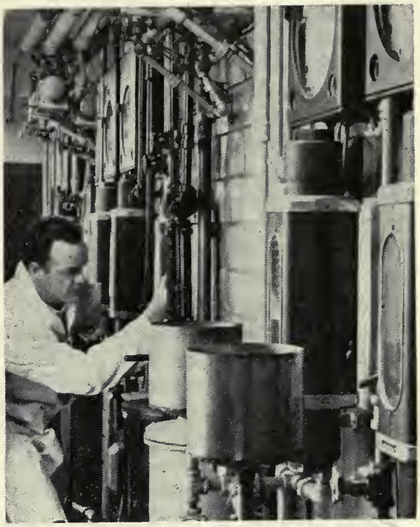
The filter is a cast-iron pot with a clamp-tight cover. The insert, or filter, consists of a perforated stainless-steel tubular holder, covered with a fine stainless-steel screen. This is wrapped with Filtocot, and finally a layer of gauze is tied around the outside to prevent any cotton from coming loose and getting into the system. The pump forces the solution around and through the filtering material to the center of the holder where it leaves through a pipe connected to the bottom of the filter holder.

The replenisher solutions are mixed in stainless steel mixing tanks on the floor above the processing machine, and flow to the machine by gravity. Each mixing tank is provided with a reserve tank of sufficient size to provide the machine with replenisher while a new tank of solution is being mixed. Lighting mixers are provided for all mixing tanks. The bleach tank is lead-lined and equipped with Saran pipes and red brass valves. Ventilation is provided for the scales used in weighing organic developers and couplers.

In order to get a consistent process it is necessary to provide regular maintenance. During the first month of operation considerable machine maintenance was required, due to the formation of organic tars in some color developers. These tars required that the color developer racks be removed from the machine each night for cleaning, and cleaning tanks were designed for this purpose. One tank holds an acid-alcohol bath, and the other a water-rinse bath. However, improvements in the process during the last year, along with operating experience in handling color developers, has greatly reduced the tar formation originally encountered. These improvements reduced the amount of rack clean-



Jet wash for removing sodium sulfide from sound track before processing continues.



Part of the control instruments to regulate temperature, rate of replenishing and rate of agitation.

ing necessary, and have decreased much of the rack maintenance which was required when the racks received a great deal of handling.

It has been found that frequent filter changes in the solution recirculating system are good economy. Clean filters provide solutions which are free from tar and sediment—and not only provide cleaner, more even development, but are also a factor in reducing rack cleaning and maintenance. Other parts of the machine must be given regular maintenance and cleaning in order to insure accurate readings and accurate performance. Filter changing and gauze cleaning are regular maintenance.

Color processing introduced the necessity of protecting operating personnel from skin irritation, or dermatitis, arising from the use of particular types of organic chemicals. Eastman Kodak Company provided considerable information and suggestions for protection in the use of chemicals, and by following these suggestions explicitly, dermatitis has not been a problem. Naturally, a few people had to learn the hard way, but once they learned it simply was not a problem.

A problem was presented in the disposal of used filter packing. Used packing is saturated with organic tars and concentrated developing by-products. Special disposal procedures were required to prevent skin irritation to those outside the company handling this refuse.

Usually the best black-and-white film operators graduate to the color machine, after being trained as black-and-white film operators. Although operation of color and black-and-white machines is generally similar, color processing requires more detailed machine work, and generally more alert operation than does black-and-white processing.

The importance of responsible solution-mixing men was established early in our color processing experience. While small errors may not necessarily be serious in black-and-white mixing, they become disastrous in color. Inaccurate solution mixing often will not appear as trouble until the solution has been in use for several hours, thus presenting difficult problems of trouble shooting and correction which may result in considerable loss of production processing time.

Specially trained chemists for solution control and analysis are also necessary. Analysis of replenishers immediately after mixing and before use is desirable, as is regular analysis of tank concentration. Analytical personnel are especially valuable when trouble shooting is required.

Color control is perhaps the most important processing responsibility. Usually supervisory personnel undertake this control work. They must be thoroughly trained in all phases of color processing, and have complete knowledge and experience in the operation of the machine and other equipment used.

Specifically, our control procedure consists of three steps: Sensitometric tests, picture strips, and print inspection. Drum-printed sensitometric tests are processed regularly, read on an Ansco color densitometer and recorded. Backing up this sensitometric information are printed picture strips developed with each sensitometric test.

Occasionally these picture strips show conditions not interpretable on the sensitometric test, and this is extremely practical for quality checking. Visual inspection of prints as soon after processing as possible is another valuable and practical method of quality control. Inspection also provides a quick check on the printing operation. By combining information obtained from these three sources,

A part of the chemical control laboratory.

it is possible to hold Kodachrome print quality within narrow and acceptable limits.

We use one group of printers, one processing machine, and by having both the printing and processing of Kodachrome film within the same laboratory, it has been possible to achieve noticeable improvement in the consistency of color quality release printing. Such consistency is noticeable in regular printing, but it shows up immediately and noticeably when it is necessary to print hard to reproduce material, such as to make prints from masters.

It would not be proper to end this paper without mentioning a few of the people who have been extremely helpful in the project from the very beginning, although it will not be possible to list them all. We were very fortunate in having Bob Sutton and Ken Curtis in our Engineering Department, along with the men who helped them in building and installing the machine. Besides the authors, Dale Musselman spent a great deal of time and thought in getting the process started, maintaining quality, and turning out production in a minimum length of time with a minimum amount of spoilage. The men who actually run the machine and mix the chemicals have been very interested in the process, and very helpful in their suggestions so that the best possible results could be obtained. It would be impossible to name personally all the people at the Eastman Kodak Company who have helped and encouraged us in getting the machine built and into operation. And, we would like to acknowledge and thank them and also the men at Ansco for their interest and suggestions in this project.

We feel the project has been a success, and perhaps the greatest factor in that success is the pride of achievement felt by each person working on it.

A System of Double Noise Reduction for Variable-Area Recording for Direct-Playback Purposes

By J. G. STREIFFERT

In variable-area recordings made for direct-playback purposes, the density of the "opaque" part of the track is established by distortion criteria and is usually so low that the signal-to-noise ratio is adversely affected. A system of "double noise reduction" is proposed which does not require the use of auxiliary lamps, slits or galvanometers. By this means, not only is the clear area of the track reduced during periods of low modulation, but also the density of the exposed area of the track outside the modulation envelope is increased in order to reduce the noise contributed by this part of the track. Tests indicate that a reduction in noise of 3 to 4 db can be expected.

It is well known that when variable-area recordings are made for direct-playback purposes, the density of the "opaque" portion of the track is usually undesirably low (1.0 or less), if the requirement of minimum distortion is met. Under these conditions, during reproduction a substantial fraction of the incident light gets through the semi-opaque part of the track and adversely affects the signal-to-noise ratio. To ameliorate this difficulty, it has been proposed by Robinson,[1] Dimmick[2] and others,[3] that what might be called "double noise reduction" be used. A drawing illustrating what this type of track would look like is shown in Fig. 1. The clear area of the track would be reduced during periods of low modulation by application of noise-reduction currents to the recording galvanometer as is the custom in making direct-playback recordings. In addition, the outer portions of the track are made completely opaque by subjecting the region outside the modulation envelope to a higher-intensity exposure than the region which carries the modulation. Previous proposals for accomplishing this end have required the use of one or more auxiliary items, such as lamps, slits, galvanometers, etc., to lay down *successive* exposures. The proposals which follow indicate means for achieving the required differential in exposure in the two parts of the track *simultaneously* and with a minimum of complication and of modification.

The problem is that of realizing a higher-intensity exposure in the portion of the track which is normally occluded by the opaque noise-reduction shutter vanes than in the portion not occluded

Communication No. 1418 from the Kodak Research Laboratories, a contribution submitted August 9, 1951, by J. G. Streiffert, Eastman Kodak Co., Rochester 4, N. Y.

Fig. 1. Drawing of a variable-area direct-positive recording with double noise reduction.

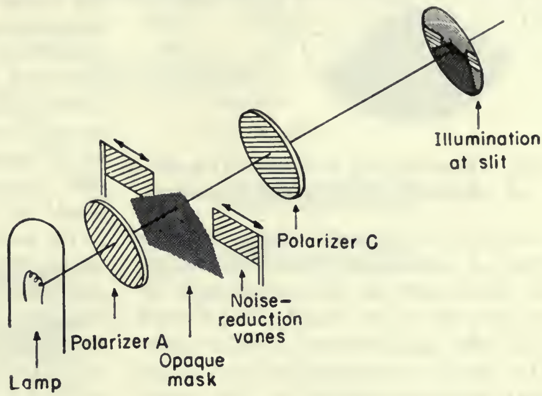


Fig. 2A. Disposition of polarizers in optical system to produce higher intensity of exposure in outer portions of track than in central portions.

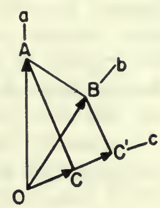


Fig. 2B. Vectorial representation of light intensity after passing through 2 or 3 polarizers.

by the vanes. Several solutions of this problem are suggested.

In Figure 2A, polarizing means are shown in the condenser system on either side of the noise-reduction shutter vanes. In addition, the noise-reduction shutter vanes are made of either polarizing film or of a birefringent material, such as mica, which produces circularly or elliptically polarized light. The two polarizing disks are adjusted for partial extinction. By proper orientation of the two disks relative to the shutter vanes, a condition is realized wherein the light intensity is greater where the beam traverses all three polarizing films than when it traverses only the two disks. This is shown vectorially in Figure 2B. If Oa represents the plane of polarization of polarizer A, and Oc that of polarizer C, then the intensity of light passing through these polarizers will be the projection of the vector, OA, on Oc, which is OC. However, where the light passes through the polarizing shutter vanes, the intensity is determined by the projection of OA and Ob, which is OB, and then the projection of OB on Oc, which is OC′. By adjusting the plane of polarization of the various polarizers, any ratio of intensity between OC and OC′ from zero to one can be attained. This provides a means for adjusting the relative exposures in the two exposed portions of the track.

Three other methods of attaining two exposure levels in the two parts of the track have been suggested by R.N. Carter.* These are shown in Fig. 3. In one method, the shutter vanes are made of semitransparent material and

---

* Patent Dept., Eastman Kodak Co.

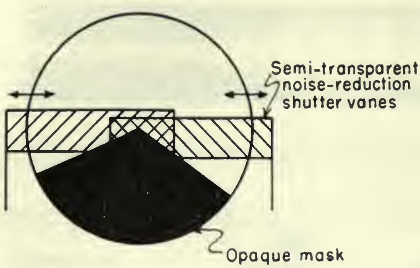


Fig. 3. Overlapping shutter-vane method of obtaining differential exposure.

overlap in the central region. For low levels of modulation, the overlap would be slight, and as the modulation increased, the vanes would move toward each other and overlap would increase. The central, modulated portion of the track would be exposed by light which had traversed two thicknesses of semitransparent shutter material, whereas the outer regions of the track would be exposed by light which had traversed only one thickness of material. The ratio of exposures in the two areas would be determined by the transmission of the vanes and would not be readily adjustable. Adjustability would not appear to be very important, however, since the density of the outer regions of the track would not be critical, the only requirement being that it be high enough to be substantially opaque, i.e., 2.0 to 2.5. If the photographic film is developed to a gamma of 3.0, this means that the outer regions of the track would have to have approximately four times the exposure of the modulated portions and that the shutter vanes would have to have a transmittance of 25%, or a density of 0.60.

The use of shutter vanes made of different colored filters has also been proposed. The difficulty of selecting different colored filters which give substantially identical exposure in the two outer portions of the track appears to make this method impractical.

Perhaps the most practical proposal is to make the two shutter vanes of polarizing material so oriented with respect to each other that where they overlap partial extinction occurs. The exposure ratio would again be fixed by the initial orientation of the planes of polarization. This system would be less wasteful of light than the other systems described. In this system, the light which exposes the outer regions of the track would be reduced to about 40% of its initial intensity, whereas in the first polarizing system described, it would be reduced to about 30% and in the semitransparent shutter system to about 25%. These figures imply that the optical system must be capable of exposing the film to a density of approximately 2.2 with a density of 0.40 to 0.60 in the beam, depending on which method is used.

In order to determine the improvement which might be expected from such a system of double noise reduction, recordings were made to simulate the effect. One-thousand-cycle signals were recorded at 5-db decrements in level from full modulation to 60 db below full modulation. From full modulation to 20 db below full modulation, the galvanometer was held in its normal, unbiased position, and the entire slit was covered with a 0.3 neutral-density filter. The exposure was adjusted to give a density of 1.0 under these conditions. The galvanometer was then tilted to produce a 0.005-in. septum on the film, and signal levels from 20 db to 60 db below full modulation were recorded, still with the neutral-density filter over the entire slit. This would correspond to maximum noise reduction as normally applied to direct positive recording, i.e., the clear area has been reduced to a minimum and the exposed area has a uniform density of 1.0. Then a duplicate of this last series of levels was recorded with the 0.3 neutral-density filter reduced in width so that it produced a 0.010-in. septum centered on the 0.005-in. septum produced by the galvanometer. By this means the

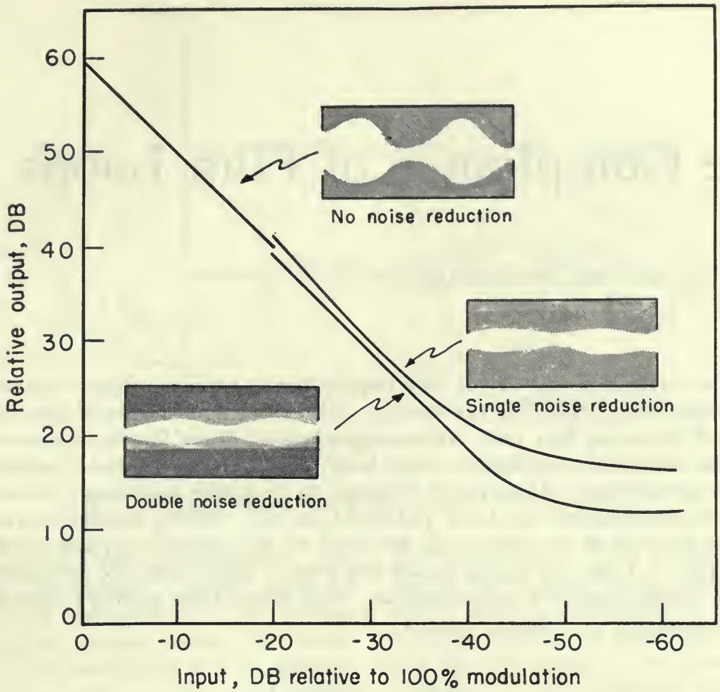


Fig. 4. Output versus input for direct-playback recordings with single and double noise reduction.

density outside the modulation was increased to about 2.0.

The output level of each section was then measured and plotted against the input level to the galvanometer. The noise spectrum was limited to the band between 500 and 8000 cycles/sec by means of high- and low-pass filters. The results are shown in Figure 4. It is seen that an improvement of from 3 to 4 db in signal-to-noise ratio could be expected from double noise reduction as compared to normal (single) noise reduction, when applied to the direct-playback type of variable-area recording. While this may not be a sensational improvement, it is clear that where a large amount of this type of recording is done, the improvement would be worth the complication.

Acknowledgment. The author expresses his gratitude to Mr. John Finkle, who made the recordings and collected the data presented here.

References

1. U.S. Patent 1,935,417, Lewis T. Robinson, 1933.
2. U.S. Patents 2,251,665, G. L. Dimmick, 1941; 2,165,787, G. L. Dimmick, 1939.
3. British Patent 546,332, Radio Corporation of America, 1942.

The Compliance of Film Loops

By GERHARD SCHWESINGER

The analysis of film drives may require the knowledge of the compliance of looped film, defined as the rate by which the length of looped film changes with changing film pull. In some mechanical filters for the suppression of film flutter the compliance of film loops acts in analogy to the capacitance of electrical filters. However, it is known to be highly nonlinear. As no complete information has been published on this subject, theoretical relations are derived in such form that they can be conveniently applied by the designer to U-shaped and S-shaped film loops. The results are compared with an earlier published approximation. The effect of film curling is shown to be accountable in a simple manner.

In some types of film drives the elastic properties of looped film sections are of considerable importance. In particular, sound-film drives utilize these properties to filter out transient and periodic disturbances which by various causes may be impressed upon the steady motion of the film. An analysis of the filtering action then requires the knowledge of a relation between the film tension and the amount of slack film in a film loop, usually referred to as the elastance or, inversely, compliance of film loops. This relation has been experimentally investigated by E. D. Cook[1] who pointed out its nonlinear character.

The theoretical treatment of the film loop problem is mathematically more laborious than might be expected. Inherently it is a matter of analytical mechanics rather than motion picture engineering and this may explain why so far no complete information on this subject has been published for motion picture purposes. An earlier theoretical treatment is due to W. J. Albersheim and D. MacKenzie[2] who derived the first two terms of a series expansion for the film slack as measured between the inflection point of an S-shaped loop and one of the drums over which the film is wound. For practical application it is desired to know the total length of slack film at a certain film tension in the loop. This information is not explicitly contained in the quoted paper. The reader might try to derive it therefrom by generalization, but he remains in uncertainty as to the validity of the result. In fact, there is no simple additive relation between (a) the total slack and (b) the partial amounts of slack as measured from the inflection point of the S-loop to the first

A contribution submitted on April 8, 1951, by Gerhard Schwesinger of the Signal Corps Engineering Laboratories (Fort Monmouth, N.J.), 617 Prospect Ave., Little Silver, N.J.

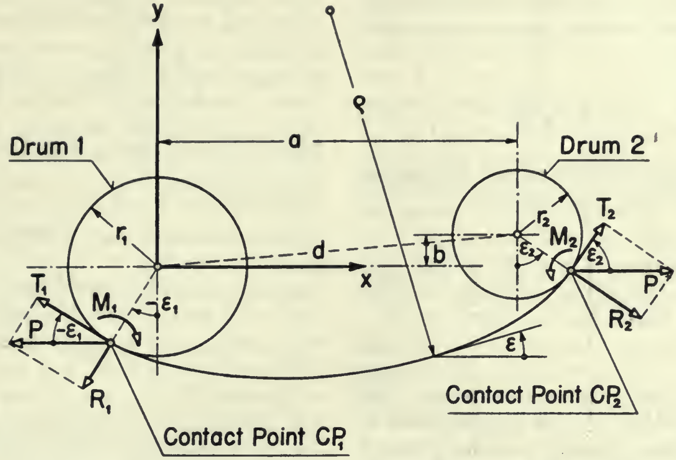


Fig. 1. Quantities entering the analysis of the loop curve.

and second drum, respectively. The earlier investigation[2] is based upon the simplifying assumption of a constant longitudinal tension along the whole loop. This assumption is only approximately true and, consequently, furnishes results of limited validity. In order to establish these limits and to complete the earlier results, the problem of film loop elastance will now be treated in a different way eliminating any arbitrary assumptions. The analysis will be extended on U-shaped loops which, having no inflection point, are not covered by the paper.[2]

While the exact solution of the loop problem can be derived in terms of elliptic integrals without much labor, it takes considerable mathematical reasoning to arrive at the first one or two members of a series expansion which alone is suitable for practical use. Unfortunately, we must say, the exact solution does not lend itself to quick numerical evaluation. It will be included here, however, for completeness and as basis of a simple approximation to be derived from it.

Figure 1 shows the two drums (1 and 2) around which the film is looped. The quantities related to one of these drums carry the subindex 1 or 2, respectively. The longitudinal forces acting on the film in the contact points CP_1 and CP_2 are T_1 and T_2, respectively. Likewise, the transversal forces are denoted by R_1 and R_2. For reasons of equilibrium the resultants of the longitudinal and transversal forces in each contact point must be equal as indicated by the equally long film pull vectors P. The bending moments in the contact points are M_1 and M_2. If EI is the bending stiffness of the film, i.e., the product of the modulus of elasticity E and the moment of inertia I of the cross section through the film, then

$$M_1 = \frac{EI}{r_1}; \qquad M_2 = \frac{EI}{r_2}. \qquad (1)$$

The difference between the moments M_1 and M_2 is balanced by an additional moment arising from the parallel displacement of the opposing force vectors P relative to each other. The center of drum 1 is now chosen as origin of a coordinate system whose x-axis points opposite to the direction of the film pull P in the contact point CP_1. If the center coordinates of the drum 2 are called a and b, and the distance between the drum centers d, then

$$a^2 + b^2 = d^2. \qquad (2)$$

Denoting the slope angle of the film loop with respect to the positive x-axis by ϵ, and setting

$$A = \sqrt{\frac{EI}{P}}, \tag{3}$$

one obtains the following differential equation of the loop curve

$$A^2 \frac{\dfrac{d^2y}{dx^2}}{\left[1 + \left(\dfrac{dy}{dx}\right)^2\right]^{3/2}} = y + \frac{A^2}{r_1} + r_1 \cos \epsilon_1 \tag{4}$$

where A is a constant parameter. The solution of Eq. (4) can be expressed in terms of the tabulated elliptic integrals of the first kind, $F(k,\varphi)$, and second kind, $E(k,\varphi)$* (see Ref. 3). For briefness, the following notation will be used

$$[F]_\beta^\alpha = F(k,\alpha) - F(k,\beta);$$

$$[E]_\beta^\alpha = E(k,\alpha) - E(k,\beta).$$

If ρ is the radius of loop curvature and s_{12} the length of the film loop between the contact points CP_1 and CP_2, one can write the solution as follows.

For the U-loop:

$$x = r_1 \sin \epsilon_1 + A\left[\frac{1 + k'^2}{k} F - \frac{2}{k} E\right]_{\varphi_1}^{\varphi} \tag{5U}$$

$$y = -r_1 \cos \epsilon_1 - A^2\left(\frac{1}{r_1} - \frac{1}{\rho}\right) \tag{6U}$$

$$a = r_1 \sin \epsilon_1 - r_2 \sin \epsilon_2 + A\left[\frac{1 + k'^2}{k} F - \frac{2}{k} E\right]_{\varphi_1}^{\varphi_2} \tag{7U}$$

$$b = -r_1 \cos \epsilon_1 + r_2 \cos \epsilon_2 - A^2\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \tag{8U}$$

$$s_{12} = kA[F]_{\varphi_1}^{\varphi_2} \tag{9U}$$

$$\frac{1}{k^2} = \frac{A^2}{4r_1^2} + \cos^2\frac{\epsilon_1}{2};\ k'^2 = 1 - k^2 \tag{10U}$$

$$\sin \varphi = \sqrt{\frac{1}{k^2} - \frac{A^2}{4\rho^2}};\ \varphi_1 = \frac{\pi + \epsilon_1}{2};$$

$$\sin \varphi_2 = \sqrt{\frac{1}{k^2} - \frac{A^2}{4r_2^2}};\ \frac{\pi}{2} < \varphi_2 < \pi \tag{11U}$$

For the S-loop:

$$x = r_1 \sin \epsilon_1 + A[F - 2E]_{\varphi_1}^{\varphi} \tag{5S}$$

$$y = -r_1 \cos \epsilon_1 - A^2\left(\frac{1}{r_1} - \frac{1}{\rho}\right) \tag{6S}$$

$$a = r_1 \sin \epsilon_1 + r_2 \sin \epsilon_2 + A[F - 2E]_{\varphi_1}^{\varphi_2} \tag{7S}$$

$$b = -r_1 \cos \epsilon_1 - r_2 \cos \epsilon_2 - A^2\left(\frac{1}{r_1} + \frac{1}{r_2}\right) \tag{8S}$$

$$s_{12} = A[F]_{\varphi_1}^{\varphi_2} \tag{9S}$$

$$k^2 = \frac{A^2}{4r_1^2} + \cos^2\frac{\epsilon_1}{2};\ k'^2 = 1 - k^2 \tag{10S}$$

$$\cos \varphi = \frac{A}{2\rho};\ \cos \varphi_1 = \frac{A}{2r_1};\ \cos \varphi_2 = -\frac{A}{2r_2} \tag{11S}$$

It is seen that the coordinates x and y of the loop curve are expressed by parametric equations with the parameters φ, ρ, respectively, the former appearing as argument of elliptic integrals. By means of the Eq. (11U) or (11S) one of these parameters can be eliminated. It is further seen that the relations are not identical for the two loop forms, which means that further investigations must be carried out separately. There is one expression, however, which is found invariant in both loop shapes, namely

$$\cos \epsilon + \frac{A^2}{2\rho^2} = \cos \epsilon_1 + \frac{A^2}{2r_1^2} = \cos \epsilon_2 + \frac{A^2}{2r_2^2} = \text{const.} \tag{12}$$

The numerical evaluation of the foregoing equations is easy only if both components T and R of the film pull vector P are known in one of the contact points, say, CP_1. In this case one knows the angle ϵ_1 and, from Eq. (12), also ϵ_2. The

* E is the adopted standard notation for the elliptic integral of the second kind and also for the modulus of elasticity. Confusion will be avoided if it is kept in mind that the latter only occurs in the product EI, but never isolated.

modulus k of the elliptic integrals can be calculated and the integrals themselves taken from tables, yielding the length of looped film, s_{12}, and the coordinates of the loop curve. Unfortunately, however, it is by far not so easy to apply the above given results to the problem of film elastance as it occurs in sound-film drives. It should be recalled that in such drives the lateral force component R is usually unknown and of no particular interest for the designer because this component does not perform work during the steady motion of the film. Thus neither ϵ_1 nor ϵ_2 is known and there is no basis other than a guess of ϵ_1 or ϵ_2 for beginning numerical calculations. In general, the distance d between the drums is fixed and the length s_{12} of the film loop is to be determined in relation to the longitudinal force component T_1. Mathematically speaking, this would require first to solve for ϵ_1 the four equations, (2), (7), (8), and (12), containing the four unknown quantities a, b, ϵ_1, and ϵ_2, and, second, to substitute the result in Eq. (9), yielding the wanted length s_{12}. Due to the transcendental character of these equations an analytical solution is impossible. The numerical solution, on the other hand, becomes very tedious as it essentially amounts to a trial-and-error procedure.

The next step to be taken toward a simplified evaluation is a series expansion of the unwieldy solution given above. Since no arbitrary assumptions are necessary to do this, the accuracy of the result can be as high as desired, depending only on the number of series terms.

First, it should be noted that for given values of the bending stiffness EI, drum radii r_1 and r_2, and center distance d, the modulus k becomes a function of only one remaining independent variable. As such one can choose the film pull P or one of its components, either at the contact point CP_1 or CP_2. One can also choose the parameter A or one of the angles ϵ_1 and ϵ_2. The preferable choice is A because then the mathematical relations become symmetrical with respect to the drum indexes 1 and 2. Furthermore, for motion picture film of inherently low bending stiffness the parameter A which has the dimension of a length is small as compared to the length s_{12} of the loops found in film drives. Small values of A/s_{12} ensure a sufficiently rapid convergence of the series and permit one to establish explicitly, in a simple form, the relationship between k and A, or k' and A, which otherwise is too complex for an explicit solution.

If the loop becomes flatter as A decreases, ϵ_1 also decreases so that, with regard to Eq. (10U) or (10S), k tends to one, k' to zero, and the quantities φ_1 and φ_2, according to Eq. (11U) or (11S), to $\pi/2$. There exist simple approximations of the elliptic integrals in the vicinity of $k = 1$, $\varphi = \pi/2$, at which point they exhibit singularities. It can be shown that in this region

$$F(k,\varphi) = \ln \frac{1 + k \sin \varphi}{\sqrt{k'^2 + k^2 \cos^2 \varphi}}, \text{ and}$$
$$E(k,\varphi) = k \sin \varphi + \frac{k'^2}{2} F(k,\varphi) \qquad (13)$$

provided that

$$\cos^2 \varphi \geqslant \frac{k'}{1 + k'}. \qquad (13a)$$

Using the approximation (13) for $F(k, \varphi)$ in connection with Eq. (11U) and (11S), one can calculate the length s_{12} of the loop. One finds:

For the U-loop:

$$s_{12} = A \sqrt{1 - k'^2} \ln \frac{A^2}{r_1 r_2 k'^2} \qquad (14U)$$

For the S-loop:

$$s_{12} = A \ln \frac{4\sqrt{(k'^2 + A^2/4r_1^2)(k'^2 + A^2/4r_2^2)}}{k'^2}. \qquad (14S)$$

If A and k' tend to zero, i.e., if the film is pulled taut between the drums, the length of the flat loop becomes s_t as it appears from Figs. 2 and 3. In order to furnish this limit value, from (14U) and (14S), k' must satisfy the condition

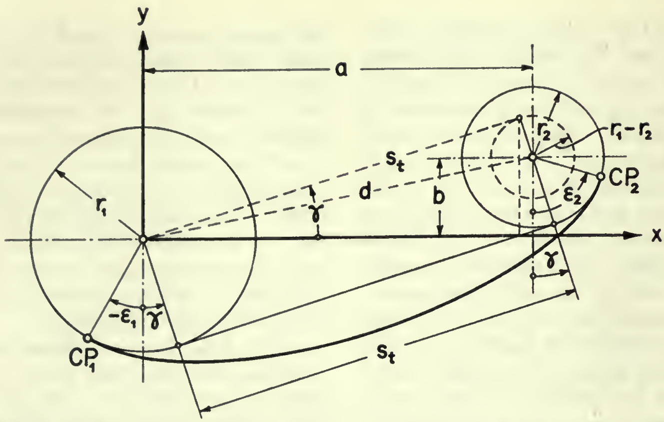


Fig. 2. Geometrical relations for calculating the slack in a U-loop.

$$k' = \frac{A}{\sqrt{r_1 r_2}} \exp\left(-\frac{s_t}{2A}\right). \qquad (15)$$

It is seen that k' tends infinitely faster to zero than A. Therefore in all later expansions terms in k' are negligible as compared to terms in A with the exception of the term

$$M = k'^2 [F]_{\varphi_1}^{\varphi_2}$$

which is not always negligible because $[F]_{\varphi_1}^{\varphi_2}$ tends to ∞. Applying the relation (15) to the approximation (13) for $E(k,\varphi)$, one obtains identically for both loop shapes

$$[E]_{\varphi_1}^{\varphi_2} = \frac{A^2}{8}\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right) + \frac{A^4}{128}\left(\frac{1}{r_1^4} + \frac{1}{r_2^4}\right) + \tfrac{1}{2}M + \ldots. \qquad (16)$$

From Figs. 2 and 3 one can read the length S of slack film in the loop as follows:

U-loop:

$$S = s_{12} - s_t - r_1(-\epsilon_1 + \gamma) - r_2(\epsilon_2 - \gamma) \qquad (17U)$$

S-loop:

$$S = s_{12} - s_t - r_1(-\epsilon_1 + \gamma) - r_2(-\epsilon_2 + \gamma) \qquad (17S)$$

Eliminating $[F]_{\varphi_1}^{\varphi_2}$ and a from the sets of Eqs. (2), (7U), and (9U), and Eqs. (2), (7S), and (9S), respectively, one obtains expressions for s_{12} which, substituted in Eq. (17U) and (17S), respectively, furnish:

For the U-loop:

$$S = \frac{k^2}{1 + k'^2}\sqrt{d^2 - b^2} - s_t + (r_2 - r_1)\gamma + \frac{2Ak}{1 + k'^2}[E]_{\varphi_1}^{\varphi_2} + r_1\left(\epsilon_1 - \frac{k^2 \sin \epsilon_1}{1 + k'^2}\right) - r_2\left(\epsilon_2 - \frac{k^2 \sin \epsilon_2}{1 + k'^2}\right).$$

Apart from negligibly small terms of the order k'^4 the last equation is equivalent to

$$S = \sqrt{d^2 - b^2} - s_t + (r_2 - r_1)\gamma + 2A[E]_{\varphi_1}^{\varphi_2} - 2AM + r_1(\epsilon_1 - \sin \epsilon_1) - r_2(\epsilon_2 - \sin \epsilon_2) \ldots (18U)$$

For the S-loop:

$$S = \sqrt{d^2 - b^2} - s_t - (r_1 + r_2)\gamma + 2A[E]_{\varphi_1}^{\varphi_2} + r_1(\epsilon_1 - \sin \epsilon_1) + r_2(\epsilon_2 - \sin \epsilon_2) \qquad (18S)$$

Eqs. (8U) and (8S), for the center ordinate b, can be transformed so that b appears as function of A. One has only to remove ϵ_1 and ϵ_2 by aid of Eqs. (10) and (12). Since in flat loops k'^2 is a negligibly small quantity, the following formula holds

$$b = -r_1 \pm r_2 - \frac{A^2}{2}\left(\frac{1}{r_1} \mp \frac{1}{r_2}\right) \qquad (19)$$

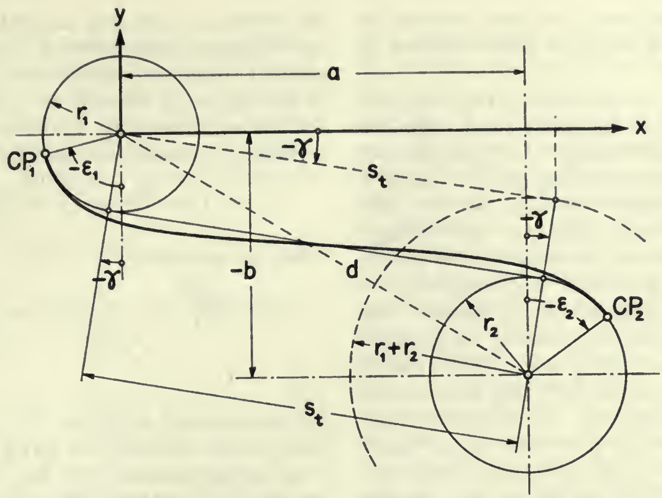


Fig. 3. Geometrical relations for calculating the slack in an S-loop.

The upper sign is to be taken for U-loops, the lower sign for S-loops. From Figs. 2 and 3 the length s_t and the angle γ are obtained as follows.

$$s_t = \sqrt{d^2 - (r_1 \mp r_2)^2}, \qquad (20)$$

$$\sin \gamma = \frac{bs_t + (r_1 \mp r_2)\sqrt{d^2 - b^2}}{d^2}. \qquad (21)$$

Again the upper sign holds for the U-loop, the lower sign for the S-loop. The expression for sin γ can be expanded in powers of A after substituting b from Eq. (19). Then the resulting series for sin γ can be converted into a series for γ. Further, the difference ($\epsilon_1 - \sin \epsilon_1$) can be expanded in powers of $\sin^2(\frac{1}{2}\epsilon_1)$ and therefrom expressed in terms of A by means of (10). The same procedure can be applied to the difference ($\epsilon_2 - \sin \epsilon_2$). Thus finally, after substituting in the two equations (18) all the expanded terms discussed above, a series expansion of the film slack S in terms of A emerges. It can be written identically for both loop shapes if a new sign convention is adopted for the two drum radii. While so far these radii were treated as positive quantities, the following sign rule may now be introduced.

U-loop:

r_1 and r_2 positive, so that
$r_1 r_2 > 0$

S-loop:

r_1 positive, r_2 negative, so that
$r_1 r_2 < 0$

The final result is

$$S = \frac{A^3}{12}\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right) - \frac{A^4}{8s_t}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)^2 + \frac{A^5}{320}\left(\frac{1}{r_1^4} + \frac{1}{r_2^4}\right) - \frac{A^2 s_t}{r_1 r_2}\exp\left(-\frac{s_t}{A}\right) + \dots \qquad (22)$$

It is seen that this series is not a true power series in A because exponential expressions appear in it. The latter are due to singularities of the elliptic integrals at that point $k = 1$, $\varphi = \pi/2$, around which the series expansion for S was required. Whether the exponential term is negligible in comparison to the highest power term given above must be decided in the particular practical application. Presumably in most motion picture applications it will be negligible. The case that the magnitude of the exponential term approaches that of the lower power terms may be considered as an indication

that the film loop is not flat enough for the limited number of series members in Eq. (22).

In order to establish a basis for the comparison of the above result with the earlier published paper,[2] the special case now is considered that the film slack S is to be measured between drum 1 and the inflection point of an S-loop. As the radius of curvature at the inflection point is infinite, one might try to derive the just mentioned special case from Eq. (22) by making r_2 infinite. However, according to Eq. (11S), $\cos \varphi_2$ would then equal zero and thus violate the condition (13a). It is therefore necessary to go back to the initial equations and to apply there the substitution $r_2 = \infty$. It can be shown that also for infinite values of r_2 the correct result is obtained from the series (22), if the vanishing exponential term is replaced by another exponential term, namely

$$+\frac{A^2 s_t}{r_1^2} \exp\left(-\frac{2s_t}{A}\right).$$

Comparing now this result with Eq. (67) of Ref. 2, one finds that the latter does not contain exponential members. The reason is that the "loop equation (60)" of Ref. 2 is only an approximation. The first series term of the quoted Eq. (67) is correct, the second term is approximately correct as the "inflection distance D" of Ref. 2 is approximately equal to s_t. It further appears that no general simple additive rule exists between the total slack S and the partial amounts S_1 and S_2, measured from the inflection point to the two drums. Only with regard to the first approximation,

$$S \approx \frac{1}{12}\left(\frac{EI}{P}\right)^{3/2}\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right), \quad (23)$$

does such an additive rule exist. It is remarkable that, in first approximation, S is independent of the drum separation d.

In order to obtain from Eq. (22) the length S, the film pull P must be known. As pointed out earlier, the designer of film drives is primarily concerned with the tangential component T of the film pull P because only this force T reflects in the torque N exerted on the drums. As it is seen from Fig. 1, the torque N_1 on drum 1, counted counterclockwise, is

$$N_1 = M_1 + T_1 r_1 = \frac{EI}{r_1} + T_1 r_1. \quad (24)$$

Using the parameter

$$t_1 = \sqrt{\frac{EI}{T_1}} = \frac{r_1}{\sqrt{\frac{N_1 r_1}{EI} - 1}} = \frac{A}{\sqrt{\cos \epsilon_1}}, \quad (25)$$

one can convert the series (22) into another series expanded in terms of t_1 so that, in conjunction with Eq. (25), for any torque N_1 the length S can be directly determined. The converted series reads

$$S = \frac{t_1^3}{12}\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right) - \frac{t_1^4}{8s_t}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)^2 - \frac{t_1^5}{320}\left(\frac{19}{r_1^4} + \frac{20}{r_1^2 r_2^2} - \frac{1}{r_2^4}\right) - \frac{t_1^2 s_t}{r_1 r_2} \exp\left(-\frac{s_t}{t_1}\right) + \dots. \quad (26)$$

The coefficients of the first two series members are the same as those of the first two members of series (22). Thus as first approximation the simple formula (23) is valid again if the tangential force T is substituted for the film pull P.

Until now the film was treated as a homogeneous flexible rod which in the absence of external forces is perfectly straight. As to homogeneity, it must be said that the perforation holes cause a periodic variation of the bending stiffness, resulting in a loop curve which is slightly wavy. This variation, however, is very small and presumably of no importance with regard to the amount S of looped film, especially if a suitable average value is assumed for the bending stiffness. On the other hand, film curling, the second offender, may sometimes produce an appreciable effect. As far as longitudinal film curling is concerned, this effect can be taken into account in the theoretical relations derived above.

Suppose the natural radius of curvature of the curling film in the longitudinal direction is constant for the considered length of film and denoted by r_n, counted positive if the film tends to curl around drum 1. Since in this case the first of the two Eqs. (1) modifies to

$$M_1 = EI\left(\frac{1}{r_1} - \frac{1}{r_n}\right),$$

the relation (25) for the parameter t_1 changes to

$$t_1 = \frac{r_1}{\sqrt{\frac{N_1 r_1}{EI} + \frac{r_1}{r_n} - 1}}. \qquad (27)$$

The loop Eq. (4) remains unchanged. This can be visualized from its physical meaning, namely, being an equilibrium condition for the moments acting on the film. If a piece of film is considered between the contact point CP_1 and any other point of the loop, it is seen that the two opposing bending moments at the ends of this piece are proportional to the change of curvature which the film has undergone when being deformed from its natural state. The difference between these two bending moments is balanced by a force couple which originates from the relative parallel shift of the opposing force vectors P at the considered points (see Fig. 1). Since only the difference between the two bending moments enters the equilibrium condition, one need consider only the difference of the changes of curvature at the two points. But in this difference the original curvature of the curled film drops out as it was assumed constant over the whole length of film. Thus the loop Eq. (4) and all ensuing relations, including the final result (26), are independent of r_n. In other words, the effect of film curling reflects only in the value of the parameter t_1 as per Eq. (27). This value in connection with Eq. (26) yields the correct length of slack film.

References

1. E. D. Cook, "The technical aspects of the high-fidelity reproducer," *Jour. SMPE*, vol. 25, pp. 289–313, Oct. 1935.
2. W. J. Albersheim and D. MacKenzie, "Analysis of sound-film drives," *Jour. SMPE*, vol. 37, pp. 452–479, Nov. 1941.
3. E. Jahnke and F. Emde, *Tables of Functions with Formulae and Curves*, Dover Publications, New York, Reprint 1945.

Auditory Perspective—A Study of the Biological Factors Related to Directional Hearing

By H. G. KOBRAK

The biological principles of auditory localization as related to stereosound reproduction are discussed. The human head carries two laterally-attached, biological sound receivers and the conduction of sound within these receivers, their position and the role of the skull in the sound field are also discussed. The attributes of the acoustic signal relevant to sound localization and the role of the central nervous system in the integration of binaural auditory stimulation are described. The factors of experience and training are stressed.

In primitive life, the sense organ of hearing has to fulfill two basic functions. It has to warn the individual of approaching danger and must enable him to seek and to find the mate. In coping with the function as warning mechanism, it is absolutely essential that the individual not only be notified that a dangerous sound has occurred, but it is equally important that the direction from which the danger lurks be known simultaneously. The ability of directional hearing must therefore be considered a basic and important function of the ear.

All attempts to explain the directional abilities of the human ear assume that the hearing organ receives stimuli which vary with the position and distance of the source. The interpretation of certain physical cues, based on past experience, is the quintescence of directional hearing. The interpretation must give information on the distance of the sound source and its direction. In the presence of several sound sources, a spatial orientation in regard to the relative position of each source is accomplished. This spatial perception of different sound sources is called auditory perspective.

Attempts have been made to create an auditory perspective in an audience. The sensation of three-dimensionality of the sound in the listener has been called the stereophonic effect. It is natural that all experiments attempting the creation of stereophonic effects must be based on a thorough knowledge of auditory perspective.

Auditory perspective is based on, and accomplished by, a number of factors.

1. Physical factors, concerning the attributes of the acoustic signal.

2. Physiological factors, concerning the biological characteristics of the human ear as sound receiver.

3. Psychological factors concerning the interpretation of acoustic cues.

Presented on May 3, 1951, at the Society's Convention in New York, by Dr. H. G. Kobrak, Division of Otolaryngology, University of Chicago, 950 E. 59th St., Chicago, Ill.

4. Coordination with the information received by other sense organs.

If a sound comes from the side, as distinguished, say, by sight, most likely a short turn of the head will be made in order to face the sound source. The movement of the neck muscles as proprioceptive stimulus and the visual clue are combined and utilized in the spatial auditory perception. Among the psychological factors there is a most important one which is responsible for the creation of the stereophonic effect: the acoustic experience of the audience. The individual will unknowingly compare his present auditory cues with similar past experiences.

How important experience is will be illustrated in Fig. 1. It is an example taken from stereovision, but it applies also to acoustic stereoperception.

Figure 1 shows three forms of plane geometry: a square and two rhomboids. Undoubtedly they are two-dimensional entities. If the three planes are put together in a certain way, most observers will perceive a three-dimensional entity, namely a cube. A person who never before saw a cube would not obtain the stereoeffect. Furthermore, it should be recognized that Fig. 1 gives not one, but two possible three-dimensional solutions. The sketch can represent a cube and also a half-open box with the left and lower sides missing. The vertical square, in such a case, appears to be farther away from the eye, while the two rhomboids appear to come toward the eye. The sketch was actually drawn for this stereoeffect. Observers visualize according to their experience. A cube is frequently encountered, while the other form would be rarely observed. Therefore, the majority will see a cube in Fig. 1.

Another comparison with the sense of vision seems in order. Stereovision is accomplished by the coordination and the integration of the perception of the two eyes. The mechanism by which the eye is able to render three-dimensional perception is considered well known.

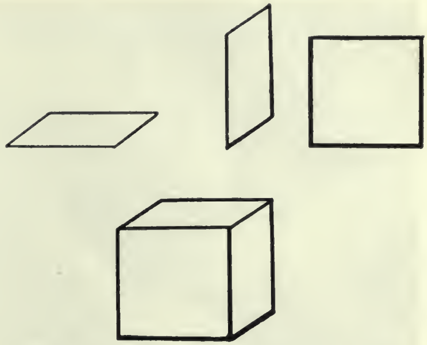


Fig. 1. The role of experience and probability in stereoperception.

The upper part of this sketch shows a square and two rhomboids. By placing these two-dimensional forms together, a stereoperception results. Most observers will see in the lower sketch a cube; a second stereoeffect (square away from eye) will be seen less frequently because a cube is an object which is more frequently encountered.

Since light travels in a straight line, the angle which the eyeball has to assume in order to face the source gives a clear definition of the direction. Since there will be a small difference in the angles which the right eye assumes, compared to those of the left eye, we have a simple geometrical problem: a base line of known dimension, i.e., the interpupillary distance and two angles. Elementary trigonometry will permit us to give direction and estimation of distance. (An important factor in distance estimation is familiarity with the objects. The size of the object should be known.)

The problems of auditory perspective are considerably more complicated because of the nature of the sound stimulus. Sound does not travel in a straight line nor does it produce sharp shadows. At least, this is true for the lower frequencies.

It must be assumed, therefore, that a simple trigonometric approach, as in stereovision, cannot solve the problems of auditory perspective. Some animals, however, utilize the position of the outer

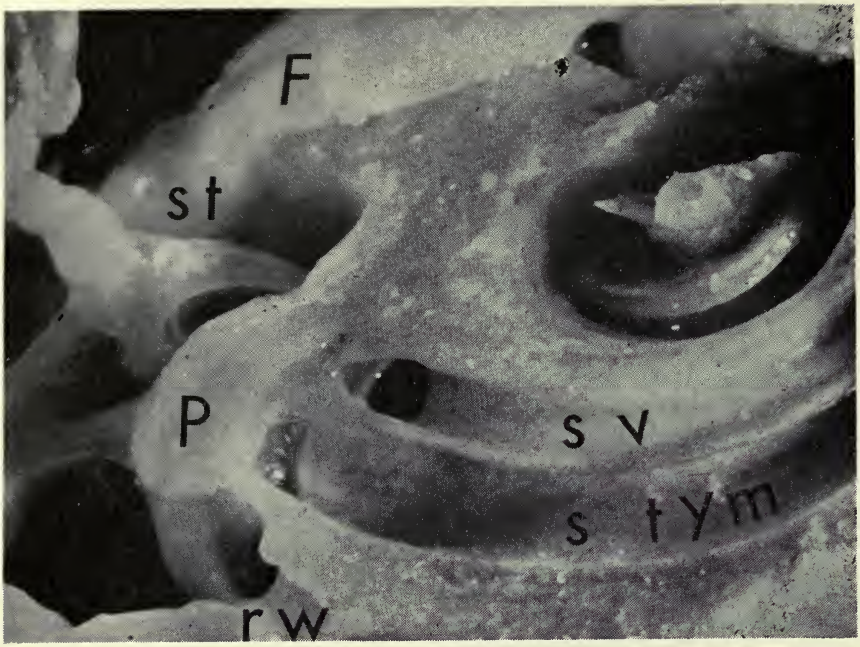


Fig. 2. The human ear. Phase relation of the two cochlear windows.

Enlarged picture of the cochlea: the stirrup, st, the round window, rw, the promontory, P, and the facial nerve, F. Under normal conditions, the stirrup executes acoustic vibrations which in turn produce vibrations of the fluid column in the scalae vestibuli, sv, the basilar membrane and the scala tympani, s tym. The round window membrane acts as a "yielding area." Its phase is opposite to that of the stirrup. This normal phase relation is essential for normal directional hearing.

In patients with destroyed sound conduction system, sound impinges onto the two cochlear windows directly and the phase of the two windows is identical. Disturbance of directional hearing results.

ear for directional hearing much as the eyes are utilized in turning toward the visual source.

Some game animals have large outer ears which are movable in all directions. The larger size and the directional qualities of the pinna in these animals give a greater hearing sensitivity for faint sounds and better directional selectivity. It has been estimated that the ear of the deer is superior to that of the hunter by 8 db in hearing faint sounds.[1] In higher-order animals like apes, and also in man, the motility of the outer ear is no longer found. With the assumption of the upright position for locomotion and improved eye and brain function, there is apparently a shift to assign to the eyes and to the brain a greater part of the judgment of directional hearing. The superior development of the brain permits a more critical and correct interpretation of the acoustic environment.

When we study the auditory perspective today, we should not overlook this development within the animal kingdom. It shows that nature has not intended the ear to be the only judge in directional hearing. It is a coordinated interpretation of acoustic stimulation in conjunc-

tion with impressions obtained from other sense organs and integrated and judged by the centers of the central nervous system.

The human ear is a biological transducer which changes mechanical waves into nerve impulses. Naturally, any bodily structure which possesses mass and stiffness will execute forced vibrations under the influence of the acoustic signal. When sound impinges onto the ear, a number of middle and inner ear structures begin to oscillate as forced vibrations. However, some structures possess an especially favorable construction and, therefore, are more effective and economical in the conduction of sound energy. Experimental evidence has shown that the eardrum, with the three attached bones (hammer, anvil and stirrup), is the best and, therefore, most important sound conductor, while conduction through the bone of the skull and through the air of the middle ear is insignificant under normal conditions.

The normal process of sound conduction through the chain of small bones in the middle ear to the oval window of the cochlea is fundamentally an impedance-matching arrangement. The elastic medium in which man lives and through which the acoustic signals arrive is air. The inner ear is filled with fluid. The ossicular chain is an impedance-matching device which bridges the air-water boundary. The footplate of the stirrup, by its acoustic oscillations, sets the fluid of the inner ear into vibrations. It is a biological underwater sound source. The vibrating fluid volumes must be considered as mass displacements. The round window membrane (Fig. 2) constitutes a yielding spot. When the stirrup pushes inward, the round window membrane moves outward. On the other hand, when the stapes executes an outward motion, the round window moves inwardly.

An experimental method was worked out at the University of Chicago by which it was possible to visualize and to photograph these vibrations within the ear under controlled experimental conditions. [As a part of the Convention presentation a motion picture was shown by which the oscillations of the stirrup and the round window membrane were seen and the phase relation observed.] This normal phase relation is important for directional hearing. Békésy[2] has carried out interesting experiments on persons with diseased ears. Patients who have lost the eardrum and hammer and anvil, either by disease or by operation, have a different phase relation between oval and round window. In these cases the predominance of ossicular sound conduction is missing. Sound waves enter the middle ear and impinge on both windows with practically the same phase. Experiments show that these patients judge the direction of a sound source opposite to that of a person with normal hearing. In cases of eardrum perforations, an artificial eardrum can be inserted which occludes the direct access of sound waves to the middle ear cavity. The directional hearing then changes again to normalcy. [The therapeutic procedure of the surgeon which brings about this reversal of directional hearing was also demonstrated by a motion picture.]

When sound impinges onto the head of an observer, a certain percentage of the total sound energy will be conducted through the bones of the skull. This pathway of sound leads directly to the inner ear without utilizing the chain of middle ear ossicles (Fig. 3). The otic capsule undergoes periodic contractions and rarefactions which produce vibrations in the inner ear fluids. The oscillations of the introcochlear fluid produce a hearing sensation which is identical to that produced by sound conduction through the ossicles. There is, however, one important difference. The direct bone conduction is a conveyance through a solid medium, therefore, a fast phenomenon. The sound conduction through eardrum and ossicular chain is measur-

Fig. 3. The human ear; concept of bone conduction; a cross section of the middle ear, M, and the cochlea, C.

The two bony canals (scalae) which are winding in 2½ coils around the axis are shown. During the process of hearing, some sound energy travels through the bone and produces waves of compressions and rarefactions of the bony capsule. This is called bone conduction (indicated by single arrows). Normally, there is a phase difference between bone-conducted sound and ossicular sound conduction. However, the influence of direct bone conduction is small in normal ears. The impulses set up in the nerve are carried through the nerve fibers in the axis of the cochlea (double arrow) and go into the central nervous system through the acoustic nerve (triple arrow).

ably slower.* Therefore, under normal conditions there is a phase difference between the direct bone conduction and the ossicular sound conduction. This phase difference has been demonstrated experimentally by Krainz.[3] Normally, the percentage of sound energy traveling through the skull bones to the inner ear is negligible compared to the conduction through the middle ear chain.[4]

However, a person wearing a hearing aid utilizes direct tissue-and-bone conduction to an appreciable extent. The phase difference between the two stimuli may be important enough to produce disturbance of the auditory perspective. Due to the fact, however, that man utilizes his past experience and his visual and tactile cues to such a large extent, this disturbance is easily checked and counterbalanced.

For natural and correct judgment of sound location both ears are necessary. The destruction of one ear creates errors

---

* The time element in ossicular sound conduction can be demonstrated in motion picture records.

in the judgment of sound direction. This can be demonstrated easily and has been known for a long time.

If one plugs an ear with cotton, apparent direction of the sound source may differ considerably from the true one. The number of persons suffering from various degrees of hearing impairment is great. It is very difficult to give exact figures: 1,500,000 to 3,000,000 children in the United States are estimated to suffer from defective hearing. Extensive surveys among adults, comparable to those of school children, are more difficult to make. One can say that roughly 5% of the future adult citizens of the nation have hearing losses.

Several factors of binaural hearing have been investigated as to their importance in sound localization.

There are several principal ways in which the sound signal reaching the right ear may differ from the sound signal incident to the left ear. The intensity of the stimulus, its phase, its wave composition and its time of arrival may differ.

An intensity difference, provided it is great enough, causes a displacement of localization toward the ear receiving the greater stimulus. This phenomenon is more important in high tones. The head is a small obstacle for low tones and its interference, therefore, negligible. However, for frequencies above 5000 cycles/sec the difference in loudness level between the two ears may be great. Steinberg and Snow[5] measured a difference of 30 db for 10,000 cycles/sec for an azimuth of 90°. The difference may be even greater for other azimuths.[6] When the sound stimulus is a complex signal, such as music or speech, then some of the high-frequency components are lost to the ear on the far side of the head and a considerable difference distortion in the composition of the signal results. Due to the shadow effect for high tones, the two auricles cast a definite shadow for tones coming from the rear.

When two tones, differing in phase, are conducted to the ears, the listener will localize the sound source toward the side of the leading phase. A sound wave coming from the side will reach the closer ear before it reaches the ear on the far side of the head. It can readily be seen (Fig. 4) that a situation may arise in which the difference in the length of the path between the two ears is greater than half of the wavelength of sound. Under such a condition, the location of the sound source on either side of the head may give the same phase difference at the two ears. Therefore, for high frequencies, localization based on phase differences becomes unreliable. The critical frequency is about 800. The wavelength of 800 cycle/sec in air is about 40 cm,

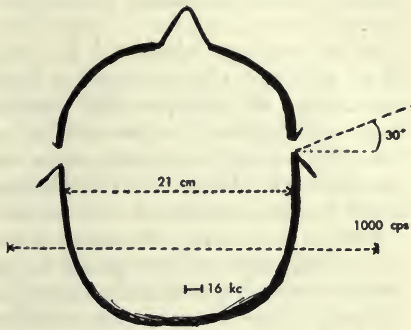


Fig. 4. The physical properties of the skull and its importance on directional hearing. Human skull seen from above.

The sketch tries to demonstrate the size of the average human head in relation to the wavelength for airborne tones of 1000 cycle/sec and 16,000 cycle/sec. It is apparent from this sketch that low tones have a wavelength which is large in comparison to the skull. The diameter of the head equals roughly one-half of the wavelength of 800 cycle/sec. High frequencies above 5000 are perceived best when entering from an angle 30° forward. This is due to the shape and position of the auricle.

The velocity of sound in air being 330 m/sec, it takes 0.0006 sec for the sound to travel a distance equal to the diameter of the head. This is the maximum time difference which can occur when a single sound falls on the ears.

which is twice the distance between the ears.

If the ears are stimulated by brief clicks with one click delivered a little earlier than the other, a single click is heard and localized on the side of the first click. Small time differences are effective. Hornbostel and Wertheimer found 30 μsec as threshold. If the time difference is increased, the apparent lateral displacement of the sound is increased until critical value is reached at 630 μsec. If the time of incidence differs more than this value, two distinct tones are heard, one on one side and one on the other. If a source of a continuous sound is near the head of an observer, the amplitude of the signal at the near ear is greater than that of the far ear. Apparently it is possible for the ear to utilize the amplitude ratio for estimation of the distance of the source. The results are rather unstable for different observers.

If a listener is permitted to move his head while determining the direction of the sound source, his ability to judge is greatly enhanced. Most people know this instinctively and move their heads while listening. If a sound comes from the front, it will appear to come from the right side when the head is turned to the left. The opposite is true when the head is turned to the right. The sound source will then appear to be on the left side. The importance of small head movements for directional sound perception can hardly be overemphasized. Some physiologists even go as far as to "explain" the juxtaposition of the cochlea and the vestibular organ in the inner ear by the coordinated body movements in relation to sound sources.

For a conscious sensation of directional hearing, it is necessary that the central nervous system (Fig. 5) receive and utilize the small differences of stimulation between the right and left ear.

Stereophonic Effect

When a listener is facing an orchestra, he is exposed to a complex sound stimulus which originates not from a pointlike sound source but from an area. The spatial relation of the various instruments can be sensed by the listener. In other words, from the influx of the various sounds he can pick out the direction from which the sound of each group of instruments comes. This is the stereophonic effect of multiple sources of sound.

Important experiments on the reproduction of spatial relation of multiple sound sources were carried out by members of the Bell Telephone Laboratories during the last 20 years.[6]

Ideally, an infinite number of microphones and loudspeakers would be needed to obtain perfect reproduction.

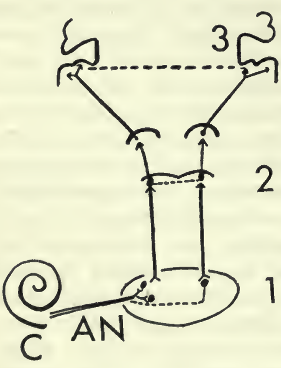


Fig. 5. Sketch of the auditory pathways in the central nervous system.

A highly simplified diagram. From the cochlea, C, of the inner ear an acoustic nerve, AN, leads to the medulla oblongata, 1. There the nerve fibers make contact with a new unit of the auditory system. A part of the fibers cross to the opposite side, the rest ascends to the next higher relay center located in the inferior collicus, 2. There another interruption and another crossing of some fibers take place. After another relay station in the medial geniculate body is passed, the auditory pathway reaches the auditory cortex, 3.

The diagram demonstrates the anatomical locations where impulses from one ear are partially transmitted to the opposite. The interplay of messages from right and left ear is interpreted by the high acoustic nerve centers and integrated into an auditory perspective. There are at least three levels known (1, 2, 3) within the central nervous system where impulses cross to the opposite side.

Experiments have shown, however, that only three, perhaps even only two microphone–loudspeaker combinations will give satisfactory auditory perspective. In the experiments of Steinberg and Snow, microphones were set on the stage and the corresponding loudspeakers were placed before an audience. The loudspeakers were placed behind a curtain. A group of observers were asked to judge from which point behind the curtain the signals appeared to originate. With three-channel reproduction, there was a good correspondence between the caller's actual position on the pickup stage and his apparent position on the virtual stage. Both attributes of forward and back as well as right and left differences were fairly well identified.

When the three-channel reproduction was reduced to a two-channel reproduction, the observers reported that the stage appeared less deep, but perhaps broader. Steinberg and Snow concluded that the loudness difference at the two ears of the observer is responsible for the accurate judgment of the angular localization.

Conclusions

The engineer who attempts to create auditory perspective in an audience should have in mind the auditory experience of his audience. If we interpret the facts of comparative physiology correctly, we come to the conclusion that the development in the animal kingdom led from a large mobile directional sound receiver (as found in fleeing herbivores) to a smaller and immobile, perhaps even rudimentary, pinna of the primates and man. Parallel to this transformation of the outer ear there is the assumption of erect posture and improvement of brain function. This means that man uses visual clues to a considerable extent. In addition, the brain will act to interpret the signals by integrating the auditory messages and comparing them with non-aural stimuli. Previous experience will facilitate the creation of a three-dimensional aspect. If there is a dog in the corner of the room and some barking is being heard from this direction, most listeners will combine the visual and auditory impression, but if there is some meowing coming from the dog's mouth, the alert listener will search around for another sound source, because his experience tells him that the meow could not have come from the dog's mouth.

Movements of the head are very important for directional hearing. Most people will make small turns of the head unknowingly while listening to a hidden sound source. If the sound source is visible, the listener will turn his head until he faces the sound source.

Normal hearing ability in both ears is the prerequisite for natural auditory perspective. One-sided deafness produces errors of sound localization. The number of persons suffering from various degrees of hearing impairment is great. However, since man utilizes visual perception to a great extent, aural deficiencies can, in most cases, be overcome without resulting in any serious auditory disorientation.

References

1. L. A. Watson and T. Tolan, *Hearing Tests and Hearing Instruments*, William & Wilkins, Baltimore, 1949. Page 10.
2. Georg v. Békésy, "Zur Physik des Mittelohres und uber das Hören bei fehler-haftem Trommelfell," *Akust. Z.*, vol. 1, p. 13, 1936.
3. W. Krainz, "Das Knochenleitungsproblem," *Z. Hals-Nasen-Ohrenheilkd.*, vol. 15, p. 306, 1926.
4. E. Bárány, "A contribution to the physiology of bone conduction," *Acta Oto-Laryngol.*, Supplement 26, p. 1, 1938.
5. J. C. Steinberg and W. B. Snow, "Symposium on wire transmission of symphonic music and its reproduction in auditory perspective," *Bell System Tech. J.*, vol. 13, p. 245, 1934.
6. L. J. Sivian and S. D. White, "On minimum audible sound fields," *J. Acoust. Soc. Am.*, vol. 4, p. 288, 1933.

Color Television—U.S.A. Standard

By P. C. GOLDMARK, J. W. CHRISTENSEN and J. J. REEVES

This paper is divided into four sections. The first deals with the actual standards as established by the Federal Communications Commission and discusses their colorimetric significance. Section II discusses the design and performance of typical commercial color-television receivers. Section III will be of special interest to the broadcaster as it describes the conversion of existing black-and-white studio equipment for color-television use. Some data on studio installation and lighting are also supplied. Section IV deals with nonbroadcast uses of color television and describes industrial color-television equipment known as Vericolor.

I. Color-Television Standards

MOST OF THE fundamental data and early developmental stages of the field-sequential color-television system have been available to the engineering profession, partly from earlier publications (also, see the paper immediately following in this JOURNAL) and partly from material presented at the FCC hearing.[1–3] Now that color television has attained the status of commercial operation, it seems advisable to fashion this paper in such a way that it is most useful to the studio and receiving-equipment engineer.

It is appropriate to begin with a recital of the official FCC color-television standards as they appeared in the *Federal Register* and to follow this with a brief discussion of their significance from a colorimetric point of view.

It is ordered, That effective the 20th day of November, 1950, the Commission's "Standards of Good Engineering Practice Concerning Television Broadcast Stations" are amended in the following respects:

(I) Paragraphs 5, 6, 7 and 8 of Section 1B entitled "Visual Transmitter" are revised to read as follows:

5. Color transmission. The term "color transmission" means the transmission of color television signals which can be reproduced with different values of hue, saturation and luminance.

6. Field. The term "field" means scanning through the picture area once in the chosen scanning pattern and in a single color. In the line-interlaced scanning

A contribution submitted September 4, 1951, by Peter C. Goldmark, John W. Christensen and James J. Reeves, Laboratories Division, Columbia Broadcasting System, Inc., 485 Madison Ave., New York 22, N.Y. This paper is being published simultaneously in the *Proceedings of the I.R.E.* This paper is, in parts, a development from the one given Oct. 16, 1950, at the Society's Convention at Lake Placid, N. Y.

[1] P. C. Goldmark, J. N. Dyer, E. R. Piore and J. M. Hollywood, "Color television—Pt. I," *Proc. I.R.E.*, vol. 30, pp. 162–182, Apr. 1942.

[2] P. C. Goldmark, E. R. Piore, J. M. Hollywood, T. H. Chambers and J. J. Reeves, "Color television—Pt. II," *Proc. I.R.E.*, vol. 31, pp. 465–478, Sept., 1943.

[3] P. C. Goldmark, "Brightness and contrast in television," *Elec. Eng.*, vol. 68, pp. 237–242, Mar. 1949.

pattern of two to one, it means the scanning of the alternate lines of the picture area once in a single color.

7. Frame. The term "frame" means scanning all of the picture area once in a single color. In the line-interlaced scanning pattern of two to one, a frame consists of two fields.

8. (a). Color field. The term "color field" means scanning through the picture area once in the chosen scanning pattern and in each of the primary colors. In the line-interlaced scanning pattern of two to one, it means the scanning of the alternate lines of the picture area once in each of the primary colors.

(b). Color frame. The term "color frame" means scanning all of the picture area once in each of the primary colors. In the line interlaced scanning pattern of two to one, a color frame consists of two color fields.

(II) Paragraphs 5, 6 and 13 of Section 2A entitled "Transmission Standards and Changes or Modifications Thereof" are revised to read as follows:

5. For monochrome transmission the number of scanning lines per frame shall be 525, interlaced two to one in successive fields. The frame frequency shall be 30, the field frequency 60, and the line frequency 15,750 per second.

6. For color transmission the number of scanning lines per frame shall be 405, interlaced two to one in successive fields of the same color. The frame frequency shall be 72, the field frequency 144, the color frame frequency 24, the color field frequency 48, and the line frequency 29,160 per second.

13. The level at maximum luminance shall be 15% or less of the peak carrier level.

(III) The following new paragraphs 19 and 20 are added to Section 2A:

19. The color sequence for color transmission shall be repeated in the order red, blue, green in successive fields.

20. The transmitter color characteristics for color transmission shall be such as to reproduce the transmitted colors as correctly as the state of the art will permit on a receiver having the following trichromatic coefficients, based on the standardized color triangle of the International Commission on Illumination:

Red	*Blue*	*Green*
$x = 0.674$	$x = 0.122$	$x = 0.227$
$y = 0.326$	$y = 0.142$	$y = 0.694$

(IV) New "Appendix I" attached hereto entitled "Television Synchronizing Waveform" is substituted for "Appendix I" of the "Standards of Good Engineering Practice Concerning Television Broadcast Stations."

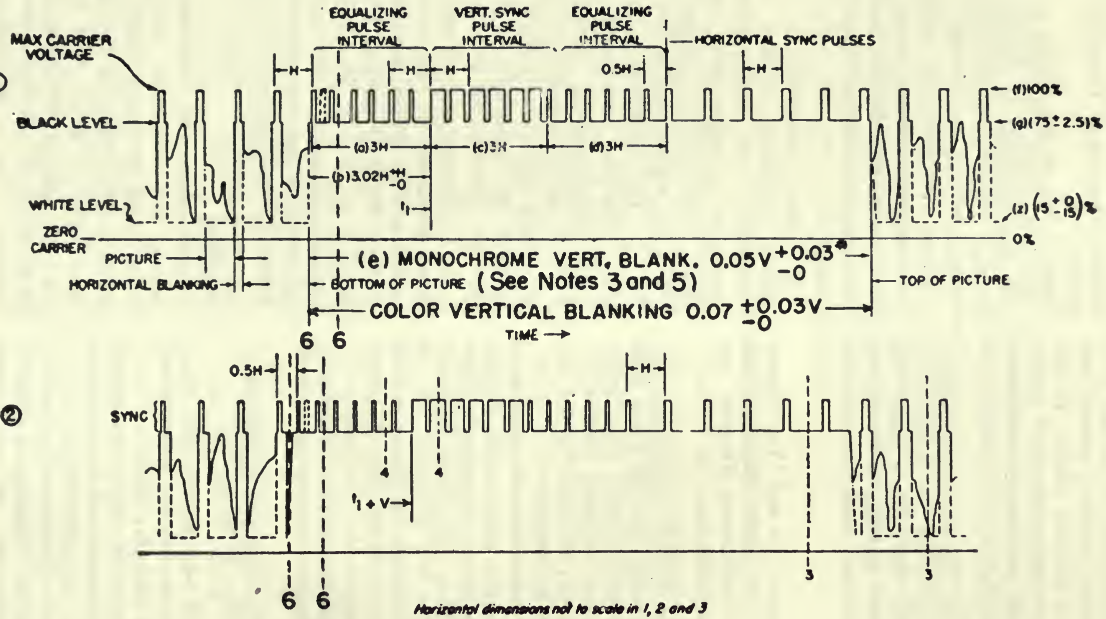
(Secs. 4, 303, 48 Stat. 1066, as amended, 1082 as amended; 47 U.S.C. and Sup. 154, 303, interprets or applies Sec. 301, 48 Stat. 1081; 47 U.S.C. 301)

Released: October 11, 1950.

Figure 1 shows the television synchronizing waveforms which combine both the black-and-white and the color waveshapes as well as their numerical values.

Referring to paragraph 20 of the preceding standards, dealing with the transmitter color characteristics, it is important to realize their real significance. The receiver primaries E to which the standards refer are shown in Fig. 2. The coordinates on the ICI color diagram correspond to those listed in paragraph 20. These primaries E satisfy certain performance conditions for specific types of color receivers. The ratios of the luminosities of these primaries are green to red to blue as 2.9 to 1.8 to 1. Because of the favorable ratios, these primaries at the receiver will permit a high flicker threshold illumination. Thus, if receiver illumination as high as 24 ft-L (foot-Lamberts) is required and a color disk is used, these primaries E are recommended. The theoretical maximum color gamut possible with these primaries is more than adequate.

Calculations and experiments, comparing the maximum possible color fidelity with primaries E using only the major positive lobes of the transmitter color curves (Fig. 3), have shown that the color fidelity obtainable is at least as good as, if not better than, Kodachrome. This is particularly true if



Legend:

1 H = Time from start of one line to start of next line
2 V = Time from start of one field to start of next field
3 Leading and trailing edges of vertical blanking should be complete in less than 0.1H
4 Leading and trailing slopes of horizontal blanking must be steep enough to preserve minimum and maximum values of (x + y) and (i) under all conditions of picture content
5 Dimensions marked with asterisk indicate that tolerances given are permitted only for long time variations and not for successive cycles
6 Equalizing pulse area shall be between 0.45 and 0.5 of area of a horizontal sync pulse
7 Color pulse area shall be between 0.45 and 0.5 of the area of a horizontal sync pulse
8 Refer to text for further explanations and tolerances

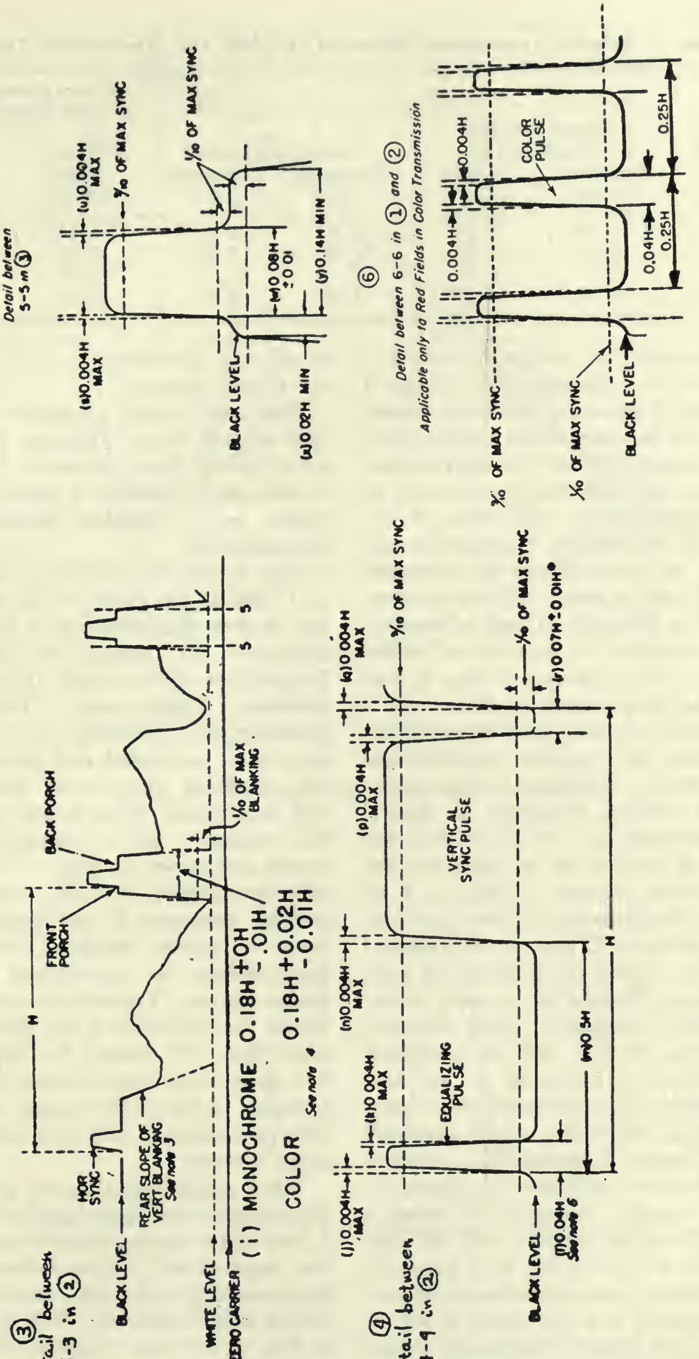


Fig. 1. Television synchronizing waveforms.

Table I. Relative Luminosity Values of Original and Reproduced Colors

Wratten filter No.	Filters through Illuminant C Published values	Filters through Illuminant C Actual values	Reproduced with Primaries C	Reproduced with Primaries A	Filters photographed with Kodachrome Type 5 Before (with 3200 K)	Filters photographed with Kodachrome Type 5 After (with 3200 K)
13	2.57	2.06	2.97	2.42	1.56	0.46
22	2.54	2.10	2.25	1.81	2.30	1.74
32	1.—	1.—	1.—	1.—	1.—	1.—
38	3.12	2.39	1.61	1.43	1.78	0.96

the distortion in luminosity values is also taken into consideration. Figure 4 and Table I show the tabulated results.

With the field-sequential system, when using a single camera, it is not practical to employ masking; that is, utilization of the negative lobes. In view of the results of the fidelity experiments just referred to, masking can be dispensed with. It will be shown that the standard transmitter primaries as used in practice, namely, without the negative and minor positive lobes, as shown in Fig. 5, can satisfy not only primaries E but also a wide variety of other receiver primaries. This gives the receiver manufacturer the necessary flexibility in the choice of color fidelity, resistance to flicker, light efficiency, etc. In Fig. 4 the color fidelity of another set of primaries has been plotted against primaries A as well as Kodachrome. They are receiver primaries C and are represented in Fig. 6. These color primaries were theoretically derived by an early industrial color committee, using Wratten filters Nos. 47, 58 and 25 combined with Illuminant C (one of the ICI illuminants). The resultant white when using equal amplitudes of red, blue and green is again Illuminant C. Another set of receiver primaries is plotted in Fig. 6, namely, primaries D using a specific phosphor mixture with Wratten filters Nos. 47, 58 and 26. Both primaries D and C show better blues than primaries A or primaries E as illustrated in Fig. 2; however, the greens of primaries A and primaries E are superior while the reds of all four primaries, A, C, D and E are almost identical.

The more recent primaries E differ only slightly from primaries A. They were derived from primaries A in such a way as to provide a more suitable white, using available phosphor-filter combinations.

The luminosity ratios of primaries A, C and D are given in Fig. 6 and it can be seen that primaries A (similar to primaries E) belong to the low luminosity-ratio primaries (high flicker threshold illumination). Transmitter primaries for primaries A, C and D have been calculated and plotted with the condition that equal amplitudes will correspond to the desired white at the receiver. These transmitter primaries are shown in Fig. 7. Actually, only two families of curves are shown because primaries C and primaries D result in almost identical transmitter characteristics as represented by the broken curves. Transmitter color sensitivities for primaries A are shown with solid lines. It should be understood that these sensitivities combine the color response of the light source, camera-tube photo-surface and color filters used at the camera.

When examining the two groups of transmitter color characteristics in Fig. 7, one will note that when disregarding the negative and minor positive lobes, the remaining shapes are almost identical except as to amplitude. Referring now to Fig. 5, the three transmitter characteristics for blue, green and red represent

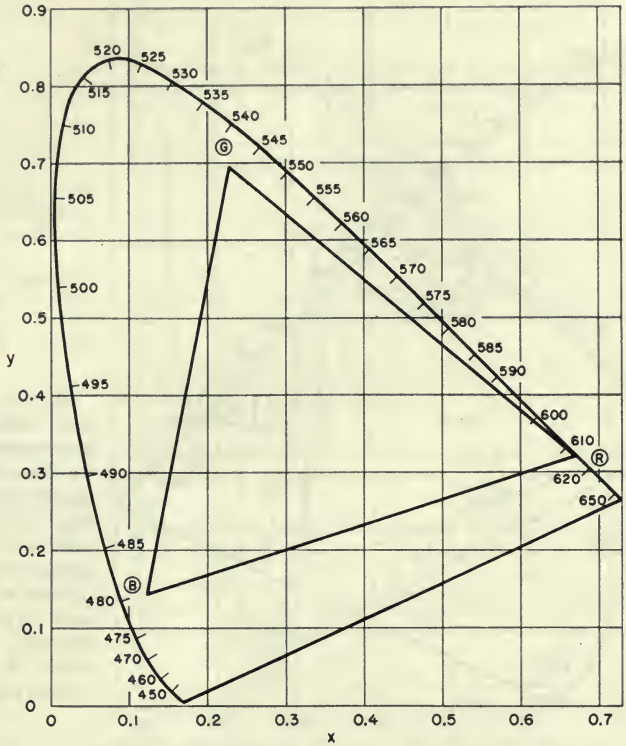
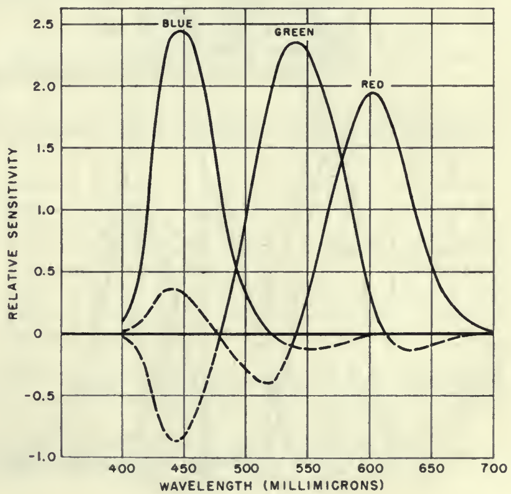


Fig. 2. Color triangle for receiver primaries *E.*

Fig. 3. Theoretical (ideal) spectral sensitivities of the transmitter based upon receiver primaries *E.* Note—White to be reproduced by equal voltages of the three primaries.



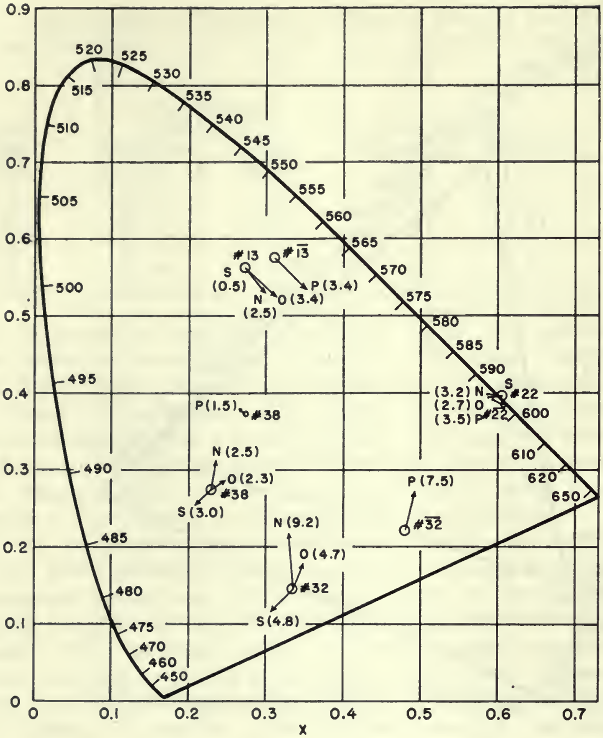


Fig. 4. Comparative fidelity of reproduction of colors by means of transmitter primaries of Fig. 3 (using only positive lobes) together with receiver primaries *C* and *A*, and type *B* Kodachrome. Note—Primaries *A* similar to primaries *E*.

Legend:
S = Published filter values
O = Reproduced with primaries C
$\mathcal{N}$ = Reproduced with primaries A
Numbers in brackets indicate approximate discernible color differences
Numbers—$\overline{13}$, $\overline{22}$, $\overline{32}$, $\overline{38}$ Filters at 3,200 K
P—Reproduced with Kodachrome type *B* and 3,200 K

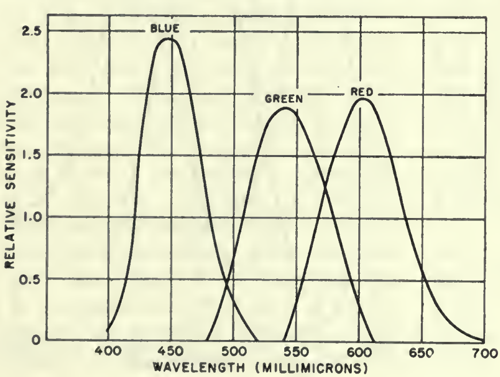


Fig. 5. Standard transmitter color primaries, neglecting minor lobes and adjusted to produce equal signal amplitudes for red, blue and green (based upon receiver primaries *E*).

Legend:

A—Low flicker synthetic primaries, White = Illuminant *C*

C—Color Committee Primaries: #47, 58, 25 Kodak filters + Illuminant *C* White = Illuminant *C*

D—(dotted line) CBS 2-phosphor with #47, 58, 26 Kodak filters

Triangle $A = \Upsilon_b : \Upsilon_r : \Upsilon_g = 1:1.5:2.4$

Triangle $C = \Upsilon_b : \Upsilon_r : \Upsilon_g = 1:4.3:12.3$

Triangle $D = \Upsilon_b : \Upsilon_r : \Upsilon_g = 1:4.9:13.4$.

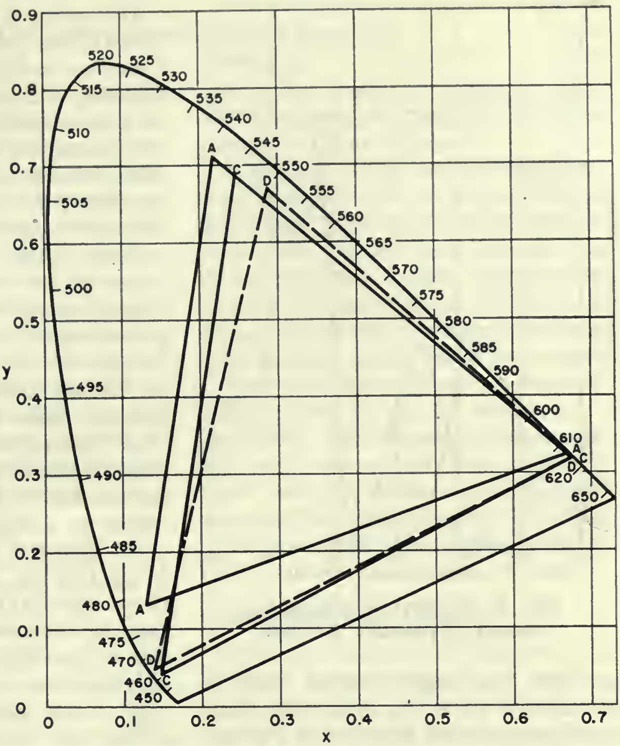


Fig. 6. Comparative color gamuts of receiver primaries *A*, *C* and *D*.

Legend:

I. Solid line = ideal transmitter color sensitivities for use with primaries *A*, reproducing white (Illuminant *C*)

II. Broken line = ideal transmitter color sensitivities for use with primaries *C*, reproducing white (Illuminant *C*)

Note—White to be reproduced by equal-signal voltages of the three primaries.

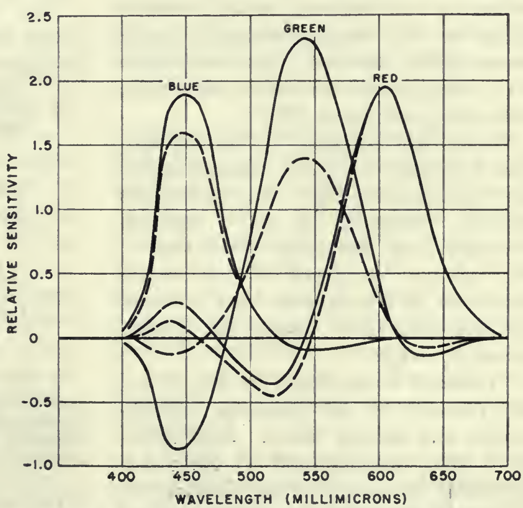


Fig. 7. Theoretical (ideal) spectral sensitivities of the transmitter based upon receiver primaries *A* and *C*.

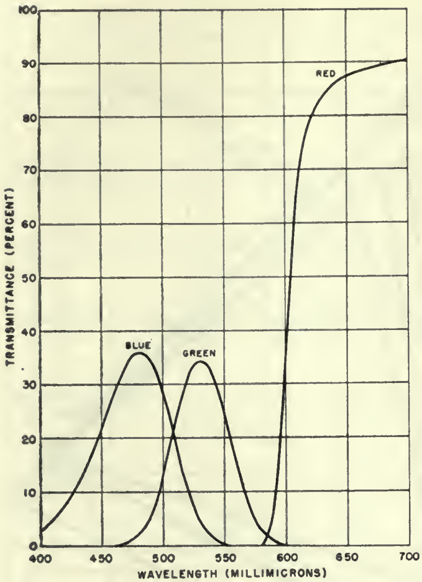


Fig. 8. Spectral transmittance curves of primary *E* filters.

not only the major positive lobes of primaries *E* from Fig. 3 but also those of primaries *A* and *C*, and thus *D*, from Fig. 7. The electrical amplitudes required to obtain the proper value of white at a receiver using receiver primaries *E*, corresponding to equal areas under the red, blue and green transmitter color sensitivities, are already taken into account in Fig. 5.

From the foregoing it can be seen that a transmitter which radiates signals corresponding to Fig. 5 will satisfy the receiver primaries *A*, *B*, *C* and *E*. Naturally, for primaries other than *E* the relative intensities of the various primaries at the receiver have to be so proportioned as to obtain the desired value for white.

Primaries *E* as shown in Fig. 2 are the product of the phosphor characteristic and specific filters. Such filters have been manufactured by Monsanto Chemical Co. and Eastman Kodak Co. in large acetate sheets. Figure 8 shows the typical transmittance curves.

The universal transmittance curves as shown in Fig. 5 require certain tolerances if they are to be used as standard. The following is an attempt to interpret the color standards in such a fashion that the transmitter characteristics are specifically defined, while at the same time permitting the utmost flexibility for the color-television receiver designer.

Given a light source illuminating the scene to be televised and having a spectral energy distribution *E*, where *E* is the radiant flux per unit wavelength throughout the visible spectrum (400 to 700 mμ (millimicron)), the overall spectral response comprises:

(a) Spectral sensitivity *S* of the camera tube, defined as its response to unit radiant flux of spectrally homogeneous energy as a function of wavelength,

(b) Spectral transmittances, *R*, *B*, *G*, of the red, blue and green color filters; spectral transmittances being the ratio of transmitted to incident radiant flux of spectrally homogeneous energy as a function of wavelength,

(c) Color amplitude factors *r*, *b*, *g*, of the color mixer, defined as the respective ratios of the outgoing and incoming individual color signals.

The camera sensitivity, the color filters and the color amplitude factors shall satisfy the following four conditions:

1. $\int_{550}^{660} ESR d\lambda \Big/ \int_{400}^{700} ESR d\lambda$ be not less than 0.90,

2. $\int_{410}^{500} ESB d\lambda \Big/ \int_{400}^{700} ESB d\lambda$ be not less than 0.90,

3. $\int_{490}^{600} ESG d\lambda \Big/ \int_{400}^{700} ESG d\lambda$ be not less than 0.90,

4. The color amplitude factors *r*, *b*, *g*, shall be adjusted so that the color signals, corresponding to a white test area* illuminated by the light source *E*, are equal within $\pm 5\%$.

* The white area of the test chart shall have a spectral reflectance substantially constant, independent of wavelength.

It is common knowledge that methods used by any color-television system for presentation of a color picture at the receiver may be used with the field-sequential system, while the converse is not true. Several of these methods are illustrated in Fig. 9. The majority are unsatisfactory for home use because of one or more of the following undesirable features: (1) difficulty of maintaining optical registration, (2) difficulty of maintaining electrical registration, (3) narrow viewing angle, (4) high cost, and (5) insufficient highlight brightness. Table II shows the undesirable features associated with each method.

Table II

Method (From Fig. 9)	Undesirable Features 1	2	3	4	5
a	X	X	X	X	
b	X	X		X	X
c	X	X		X	X
d	X	X			X
e					X
f					X
g					
h					
i		?		?	

The direct-view color tube will likely offer a convenient method, when developed to a commercial product at a reasonable price. Of the remaining tabulated methods, at present only the last three yield sharp color pictures usable in the home, and only the last two are capable of generating bright and sharp enough pictures for suitable home viewing in a normally lighted room. Both of these employ direct view with standard tubes; one uses the color disk and the other, the color drum.

With proper arrangement of disk and raster, a color disk need be only slightly larger than twice the tube diameter. For home use disks larger than 27 in. ($12\frac{1}{2}$-in. tube, enlarged to 16-in. picture) have not been employed. The arrangement most frequently used is a $22\frac{1}{2}$-in. disk in combination with a 10-in. tube, yielding a $12\frac{1}{2}$-in. picture.

The color drum provides large unmagnified color pictures within a reasonably sized cabinet. Several types of drum color receivers built around 17-in. rectangular tubes have demonstrated excellent picture qualities. There is no reason why 20-in. or larger direct-view color pictures cannot easily be obtained.

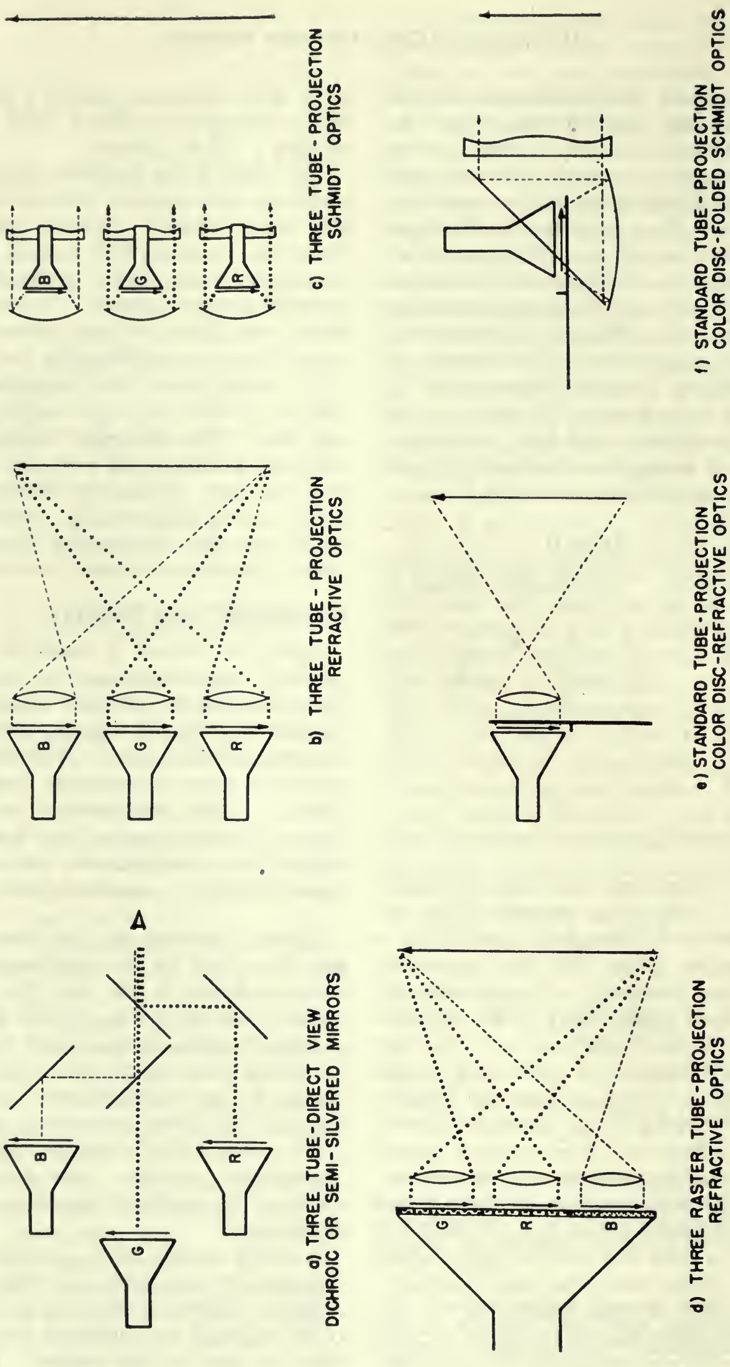
The color drum, first employed by CBS in 1940–41, will be described at a later date. The remainder of this paper will deal in some detail with two of the most recently developed commercial-type receivers employing the color disk. These are the combination color receiver and the slave color receiver.

Combination Color Receiver

With the advent of standard commercial color television, a modern home television receiver should be capable of receiving equally well both monochrome and color. It should also have the ease of operation presently associated with monochrome receivers. The combination receiver here described satisfies these requirements and is designed to sell at a moderate price.

Physical Characteristics. The dual color disk drive used in the combination receiver is shown in Fig. 10. The main chassis is shown in Figs. 11 and 12 and a detailed schematic is given in Fig. 13. Including rectifiers, 23 tubes are used. Except for the dual frequency scanning and the disk drive mechanism, the receiver is essentially the same as a standard monochrome receiver; discussion will therefore be confined largely to these differences.

A 10FP4 picture tube is used for both monochrome and color. In both cases a $12\frac{1}{2}$-in. picture is obtained by means of an oil-filled lens fastened integrally with the front of the cabinet. In the


a) THREE TUBE-DIRECT VIEW
DICHROIC OR SEMI-SILVERED MIRRORS
B
G
R
b) THREE TUBE - PROJECTION
REFRACTIVE OPTICS
B
G
R
c) THREE TUBE - PROJECTION
SCHMIDT OPTICS
B
G
R
d) THREE RASTER TUBE-PROJECTION
REFRACTIVE OPTICS
G
R
B
e) STANDARD TUBE-PROJECTION
COLOR DISC-REFRACTIVE OPTICS
f) STANDARD TUBE - PROJECTION
COLOR DISC-FOLDED SCHMIDT OPTICS

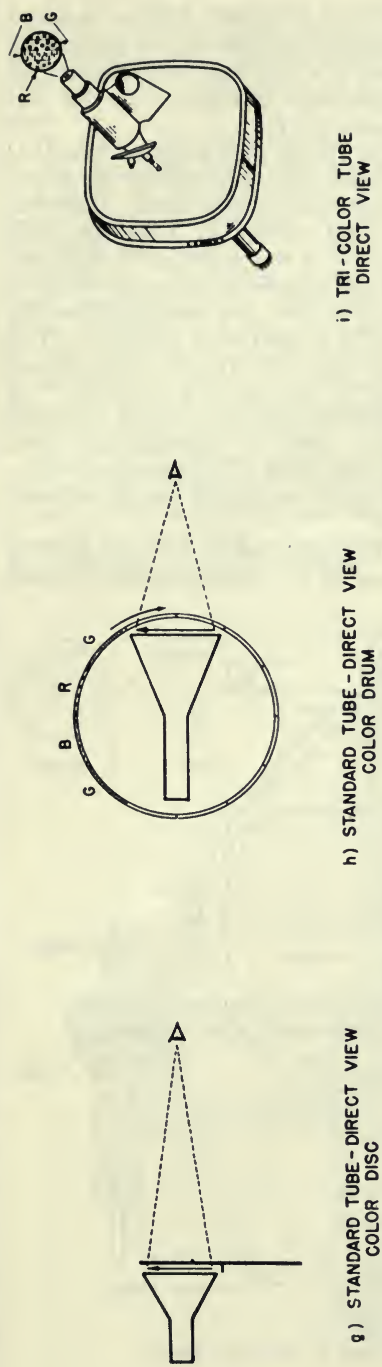


Fig. 9. Color television picture presentation methods.

dual disk arrangement only one-half of each disk is covered with filters, the other one-half being transparent. This permits the disks to be relatively phased so as to provide between the tube and the observer continuous filters for color operation or, when stopped, only clear sections for monochrome operation. The disk assembly rotates between the tube face and the back of the lens.

In this set, for the sake of economy, the color-pulse separator is omitted and the color disk is synchronized from the vertical pulses. Since these pulses contain no color information, a color-phasing button on the front panel is provided (which has to be pressed no more than twice) to obtain the correct colors. In other units, containing the color-pulse separator, this color-phase button, of course, is not required.

A front panel color-monochrome switch permits manual selection of either of the two standards. When this switch is thrown to monochrome, the following takes place automatically: the scanning is changed to the monochrome rates; the dual disk is stopped with the clear disk sections superimposed; and the clear sections are rotated to a position over the tube face where no filters are visible.

Color-Disk Drive Mechanism. An important requirement for a color-disk drive mechanism and associated circuits is to maintain accurate disk phasing even when operating under changing temperatures, adverse conditions of varying line voltages and frequencies, and variable signal inputs. Further requirements are rapid acceleration of the disk to synchronism upon the application of power and short disk pull-in time, i.e., the time required to synchronize a disk after selecting a particular station. Moreover, electrical interference should be absent and weight, size, cost and mechanical noise should be a minimum.

The combination receiver disk drive mechanism shown in Fig. 10 satisfies

these requirements. Proper phase within $\pm 2°$ over the normal range of operating temperatures is maintained with line voltages between 105 and 125 v and with line frequencies between 59.5 and 60.5 cycles/sec. The unit generates no electrical interference, has no rubbing contacts, and operates with a minimum of mechanical noise and vibration. It is designed to operate with a standard motor, a toothed rubber-fabric belt drive, and other components relatively easy to obtain.

As shown in Fig. 10 the dual disk assembly, generator, brake, and resiliently mounted induction motor are all fastened to a supporting baffle. Also mounted on the back of the baffle is the kinescope supporting structure. The disk housing is fastened to the front of the baffle by twist-lock screws. This housing completely encloses the disk in a fairly airtight space. Such an enclosure is important in order to keep disk driving power to a minimum and to retard the accumulation of dust on the disk and picture tube face.

The motor is a standard four pole capacitor induction type with the following operating characteristics: It delivers 23 in.-oz. torque at 1748 rpm with 80 to 85 v rms input at 60 cycle/sec. It is also capable of delivering the above torque at 1764 rpm with approximately 90 to 95 v input at 60 cycle/sec. This latter condition corresponds to operation at 1748 rpm at 59.5 cycle/sec. A centrifugal switch is provided internally which opens at approximately 1700 rpm and closes at approximately 1600–1650 rpm; its purpose will be described later.

The motor drives the disk shaft by means of a rubberized-fabric toothed

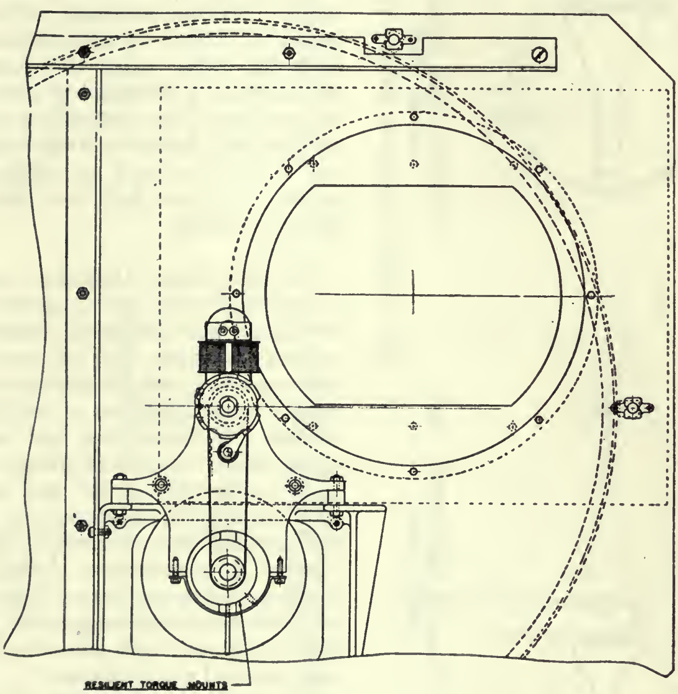
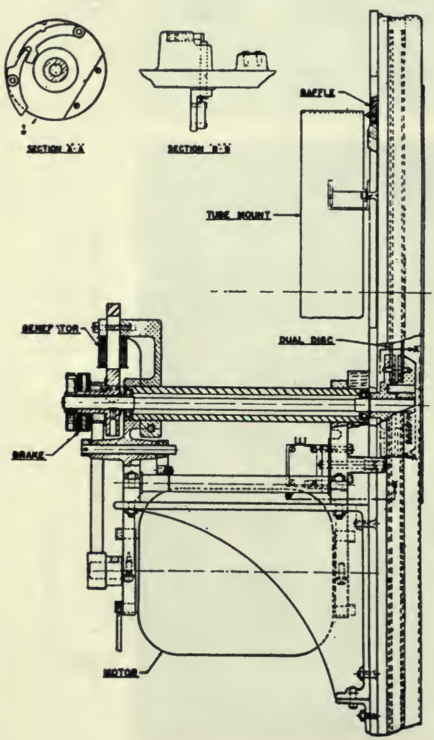


Fig. 10. Dual color-disk drive (cont'd. on next page).

timing belt, which maintains a constant speed ratio of 17/14 between the motor and the disk. With the disk rotating at 1440 rpm the motor rotates at $1748\frac{4}{7}$ rpm.

The front color disk is fastened solidly to the disk drive shaft, while the back disk floats on the shaft and is free to rotate back and forth with respect to the front disk through approximately $\frac{1}{3}$ revolution. A centrifugally operated catch mounted on the back disk, as shown in section A-A Fig. 10, prevents it from rotating backward beyond a predetermined point. At this point the catch actuates a microswitch whose function will be described later.

When the disks are rotating rapidly forward the centrifugal catch withdraws and is inoperative, and the air drag on the back disk causes it to lag the maximum amount. Under this condition the filters on one disk are adjacent to the clear area on the other disk, thereby providing in front of the picture tube a succession of six color filters, as required for color operation.



When the receiver is switched to monochrome, the brake is engaged and the motor is reversed. The disk assembly is rapidly brought to a stop and is then slowly rotated in a backward direction by the motor. The centrifugal catch stops the back disk, while the front disk continues to rotate until the back disk leads the front disk by the maximum amount, at which time the centrifugal catch actuates the microswitch, turning off the motor. This leaves the two clear areas of the disks adjacent to each other and over the tube face, as is required for monochrome.

The brake mechanism consists of a simple friction plate notched on its periphery and mounted under tension between two felt plates keyed to the disk drive shaft. During operation, a stationary latch engages the brake plate at its periphery.

The reluctance-type generator consists of a magnetically hard U-shaped stator with a coil around each leg and a magnetically soft rotor. It is magnetized by discharging a heavy electrolytic condenser through the coils while the generator is running.

The stator and rotor pole pieces are shaped to provide a saw-tooth wave output of approximately 200 v peak-to-peak. This saw tooth has a very steep downward slope of approximately 10 v per degree disk rotation, which limits the variation of disk phase to approximately $\pm 2°$ over the wide range of operating conditions described previously.

Precision ball bearings with sealed-in lifetime lubrication are used to float the color disk drive shaft. These require no care, retain low and constant friction over a wide range of operating conditions, and eliminate any oil seepage onto the color disks.

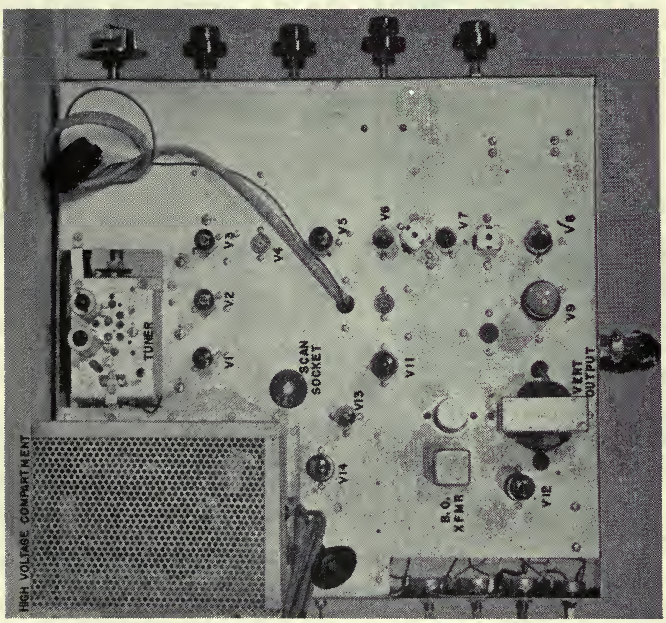


Fig. 11. Combination receiver chassis, top.

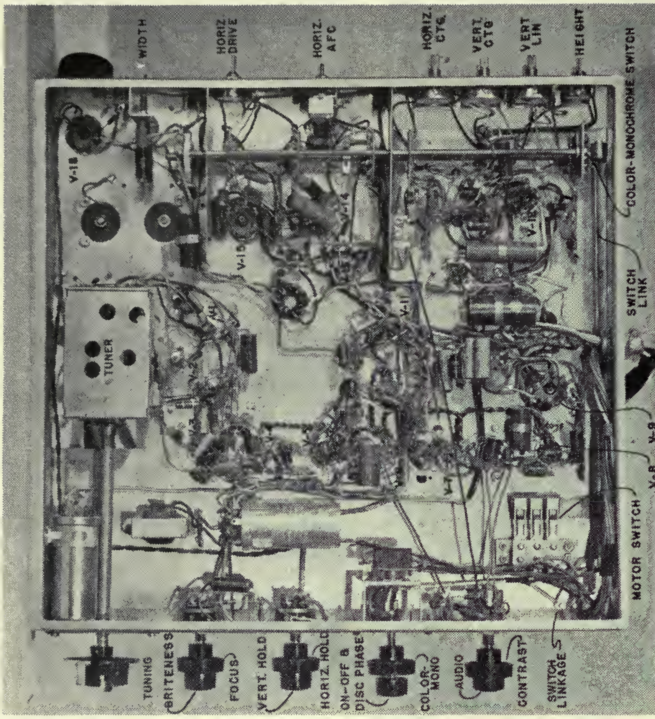


Fig. 12. Combination receiver chassis, bottom.

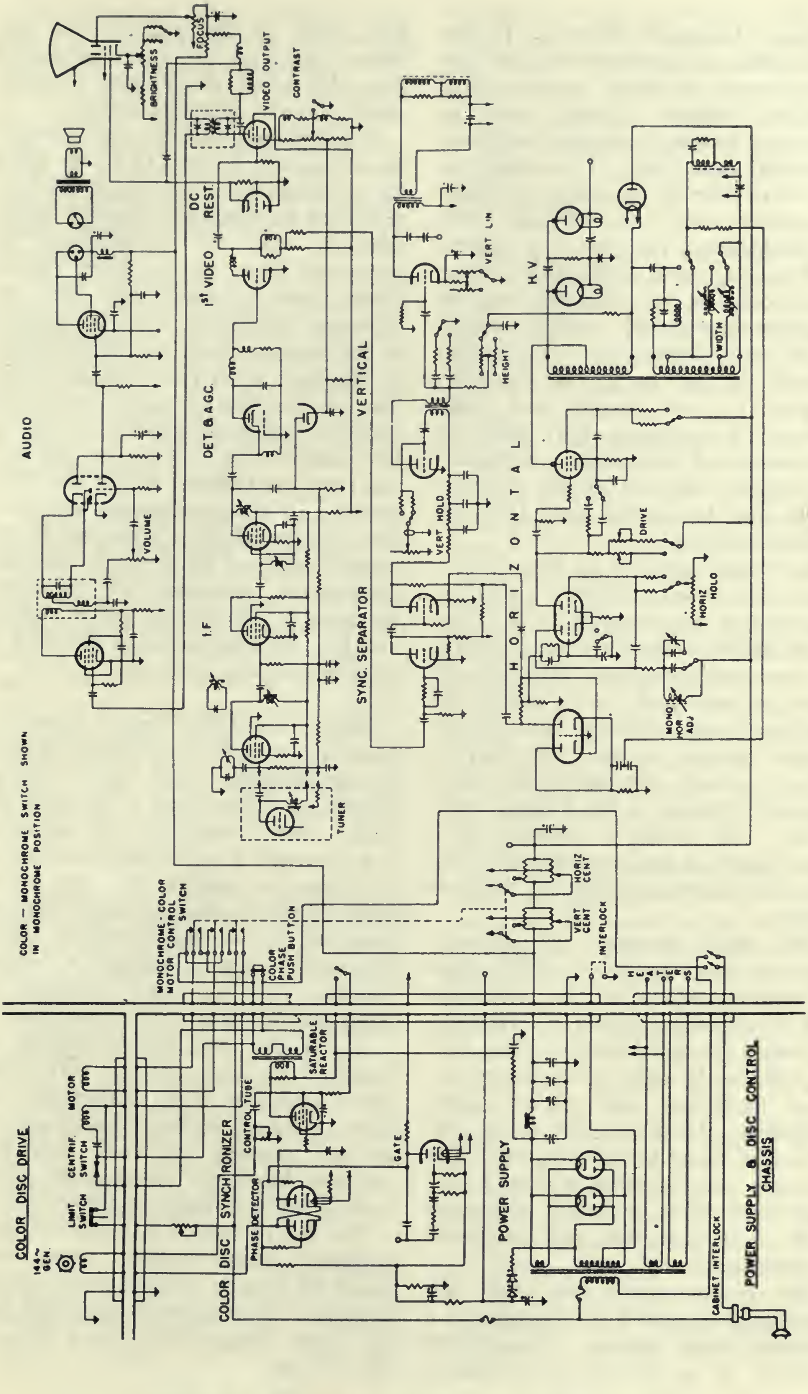


Fig. 13. Combination receiver schematic.

Chassis Component Placement. In the combination color-monochrome receiver it is necessary to switch components of normally isolated circuits, such as vertical deflection, horizontal oscillator, horizontal output, etc. This results in a somewhat different placement of chassis components than that normally used on monochrome receivers. As evident in Fig. 12, most color-monochrome switch contacts are connected to the so-called screw-driver controls located on the rear chassis skirt. A practical location of the switch is, therefore, adjacent to, and parallel with these controls. To maintain short leads, the components of the various horizontal and vertical deflection circuits obviously should also be located near their respective switches.

The chassis layout of the combination receiver is shown in Figs. 11 and 12. Arranged in line along the rear of the chassis are the vertical scanning circuits, the horizontal oscillator circuits and, under a perforated metal shield, the horizontal output circuits. Beneath the chassis, parallel to the rear "screw-driver" controls and under the corresponding circuits, is the ganged wafer switch. The switch is actuated by a connecting rod and rocking arm mechanically linked to a knob on the front panel.

The close placement of adjacent electrical components is evident from a cross-comparison of the schematic with the chassis arrangement. From the RF tuner, the signal travels a short path through the IF strip to the second detector and first and second video amplifiers. At the second video amplifier the signal branches to the audio and the synchronizing separator circuits; from there it travels over short paths to the vertical and horizontal scanning sections.

The power supply and color disk synchronizing circuits are mounted on a separate small chassis. Components sensitive to a 60-cycle/sec magnetic field, such as the picture tube and vertical oscillator, are thereby separated from the power transformer, the filter choke and the saturable reactor.

It is very important that the 60-cycle/sec component be kept to 50 db below the peak-to-peak color signal in both video and synchronizing circuits. Larger amounts may be characterized by horizontal jitter, vertical jitter, picture flutter, poor interlace, etc. The 60-cycle/sec component may be injected by the magnetic fields mentioned above, by filaments, or by power supply ripple. One of the most sensitive areas with respect to magnetic fields is the neck of the picture tube. In earlier receivers this tube was shielded with a mu-metal funnel. In the combination set, however, the overall hum is reduced to the desired low level by properly orienting components radiating 60 cycle/sec, by using a well-filtered power supply, and by observing the usual practices of twisting filament leads, etc.

RF, IF and Video Circuits. Since the horizontal scanning rate of color pictures is approximately twice that of monochrome, it is important to preserve the higher video frequencies. In addition, it is necessary that the video output be as linear as possible over the entire video band in order to avoid contrast distortion in the color picture. Such distortion is less noticeable in monochrome, since in color television it manifests itself as poor color rendition.

It has also been found desirable to switch both contrast and brightness when switching from monochrome to color, since an optimum color picture as seen through the color disk has excessive brightness and contrast when seen in black-and-white without disk.

The RF-IF section is composed of a standard Sarkes-Tarzian tuner, two tuned IF pairs in cascade, and a second detector. Its response is essentially flat to 3.7 mc (megacycles) and is down 3 db at 4 mc.

The video amplifier consists of one-half a 12AU7 triode first video stage and a 6AQ5 output video stage. The second half of the 12AU7 is used as a d-c restorer. With three volts peak-to-peak input, 120 v peak-to-peak are realized at the kinescope grid. The 6AQ5 stage is capable of 130 v peak-to-peak without appreciable amplitude distortion.

A degenerative-type contrast control in the 6AQ5 cathode circuit is frequency compensated to provide essentially uniform frequency response throughout the control range. For monochrome the maximum video level is lowered by switching a 560-ohm resistor into the contrast control circuit.

Audio Circuits. These circuits are identical to those used in monochrome. The IF trap attenuates the sound carrier approximately 10 db. The 4.5-mc inter-carrier signal is removed from the plate circuit of the video output stage. A 6AU6 amplifier drives a 6T8 stage, which is a combination ratio detector and first audio amplifier. Additional audio amplification is provided by the 6V6GT audio output stage, which also acts as a dropping resistor and regulator for the 150-v supply.

Synchronizing Circuits. Synchronizing signals are derived from the 12VH7 first video amplifier. This provides signals of essentially constant amplitude independent of contrast adjustment.

The noise immunity of the synchronizing signal separator is improved through the use of a combination long- and short-time-constant coupling circuit. The usual phase-inverter type second triode delivers the separated signals to the vertical oscillator and the horizontal phase detector diode.

Vertical Oscillator and Output Amplifier. A 12BH7 is used as a vertical blocking oscillator and output stage. Necessary circuit changes between color and monochrome are provided by five SPDT switches which act at the following points: (1) vertical oscillator grid return resistor (vertical hold), (2) *RC* charging network in the plate circuit of the vertical oscillator, (3) height controls, (4) linearity controls, and (5) centering controls.

Horizontal Oscillator and Output Amplifier. A 6AL5 phase detector controls the 12BH7 horizontal multivibrator in the usual manner. A 6BG6G horizontal output tube, a 6U4GT damper and a pair of 1X2 voltage doubling rectifiers provide adequate 55° scan and a h-v potential of approximately 15 kv.

Nine monochrome-color SPDT switches provide circuit changes at the following points: (1) AFC time-constant capacitor in the grid circuit of the horizontal oscillator, (2) flywheel *LC* tuning capacitor in the plate circuit of the horizontal oscillator, (3) fixed resistor in series with the horizontal hold control, (4) horizontal drive control potentiometers, (5) *RC* charging network in the output of the horizontal oscillator, (6) 6BG6G screen voltage, (7) yoke tap on the horizontal output transformer, (8) width controls, and (9) centering controls.

A special horizontal output transformer developed specifically for use on both color and monochrome frequencies is employed. The construction of this transformer is conventional and a ferrite core is used. Pertinent constructional details are shown in Fig. 14.

In this type of dual-frequency transformer the leakage reactance may resonate with the distributed capacitance, resulting in undesirable "ripples" on the left edge of the raster. This effect is eliminated in the combination receiver by connecting, for monochrome, a highly damped tuned circuit in the transformer secondary. As indicated in Fig. 13, this circuit is a parallel combination of a 200-μh (microhenry) inductance, a 1000-$\mu\mu$f (micromicro-

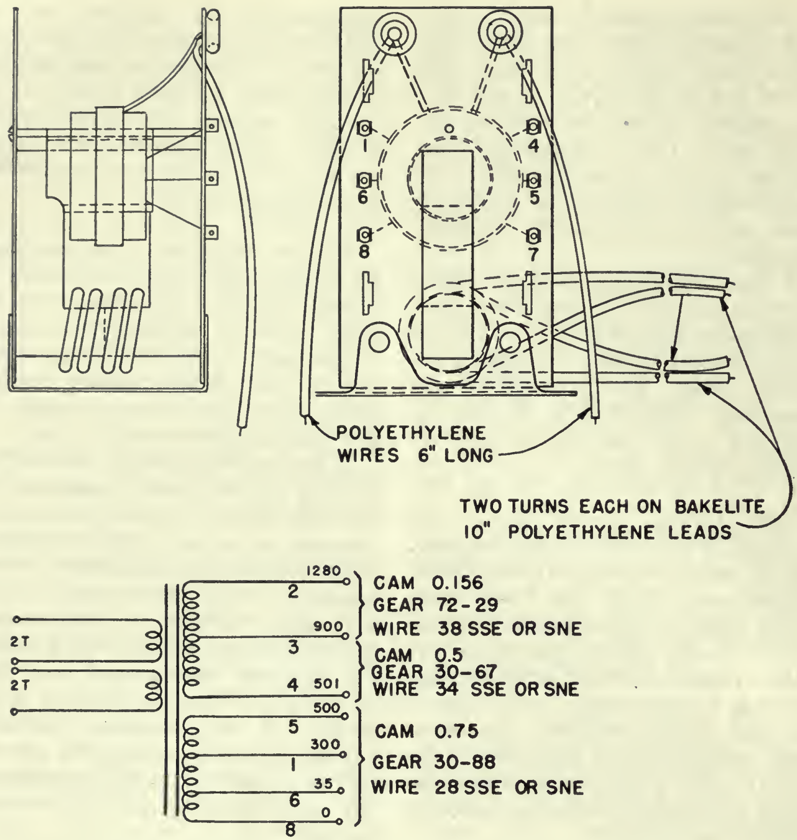


Fig. 14. Dual frequency horizontal output transformer.

farad) capacitance, and a 5000-ohm resistor.

A conventional monochrome anastigmatic scanning yoke is used. This again employs a ferrite core. The vertical and horizontal windings are of a type with inductances of 50 mh (millihenry) and 8.3 mh, respectively.

Color Disk Synchronizing Circuits. As indicated in Fig. 13, a pulse gate, a phase detector, and a saturable reactor control tube are used for color disk synchronization. The saw-tooth wave produced in the disk shaft generator is applied to both sections of the phase detector tube. This tube conducts momentarily only when excited by the vertical pulses. The clamped voltage appearing at the grid of the control tube is therefore dependent upon the relative phase relationship between the vertical pulses and the locally generated saw-tooth wave. A variation of control tube current causes a corresponding change in the degree of saturation of the motor control reactor, thereby varying the speed of the color disk.

If, for example, the disk momentarily slows to slightly below synchronous speed, the point on the locally generated saw-tooth wave at which the vertical

pulses clamp moves upward, thereby decreasing the bias on the control tube. The increased control tube current increases the degree of saturation in the motor control reactor, thereby increasing motor and disk speed to synchronism.

The pulse gate provides velocity correction of the color disk. This tube is normally conducting, thereby preventing the vertical pulses from reaching the phase detector. The locally generated saw-tooth wave from the generator is differentiated and applied to the grid of the gate tube in such a manner as to make it nonconducting only during the downward steep portion of the saw-tooth wave. Thus the operation of the phase detector is permitted during this period only. With this arrangement the *average* bias appearing at the control-tube grid is high when the disk is running considerably over speed, and low when running considerably under speed. This provides effective disk velocity correction.

In the color disk synchronizing circuits, as in most servomechanisms, an anti-hunt network is required to eliminate hunting. Such a network is provided by the 20,000-ohm resistor, 16-μf electrolytic capacitor, and 2-μf paper capacitor at the screen of the control tube and the 250,000-ohm potentiometer between the saw-tooth generator and ground. This network returns from the control tube to the phase detector the necessary amount of phase-shifted anticipating voltage to prevent hunting. Optimum anti-hunt adjustment is provided by the 250,000-ohm potentiometer.

Changes in type of color disk (as to its inertia), motor, or saturable reactor usually require corresponding changes in the anti-hunt feedback network.

Color Disk Synchronizing Operation. In effect, three separate operations pull the disk into synchronism and keep it there. When power is first applied, the centrifugal switch in the motor is closed, shorting the a-c windings of the saturable reactor. Full line voltage is thereby applied to the motor, causing rapid acceleration of the color disk to near synchronous speed. The centrifugal switch then opens and the saturable reactor with its associated circuits takes control. The velocity correcting circuits bring the disk to synchronous velocity, at which time the phasing circuits bring the disk into exact phase and maintain it there. Only ten to fifteen seconds is required to bring the $22\frac{1}{2}$-in. disk into synchronism and phase from a standstill. When running, the disk synchronizes in less than one second.

Power Supply. The power supply in the combination color-monochrome receiver is similar to that of any good monochrome receiver. As discussed previously, both the 60- and 120-cycle/sec hum components are kept very small. Decoupling is provided between the terminals supplying the disk synchronizing circuits and those supplying the remainder of the receiver. This eliminates any low-frequency variation of picture size, brightness, etc., induced by the action of the color disk synchronizing circuits. These circuits require a relatively constant current of 10 to 30 ma (milliampere) while the disk is in synchronism, but during the time the disk is being pulled into synchronism the current may vary at a slow rate between approximately 0 and 60 ma, with a corresponding induced variation in power supply voltages.

Two 5V4G cathode-type rectifiers prevent high-voltage surges when the receiver is first energized. After filtering, 390 v at 240 ma is available.

A selenium half-wave rectifier is connected to one side of the high-voltage winding of the power transformer to provide the negative voltages for the electrostatic picture tube focus and the disk control circuits.

Slave Color Receiver

Of universal interest to present television set owners is how to use present

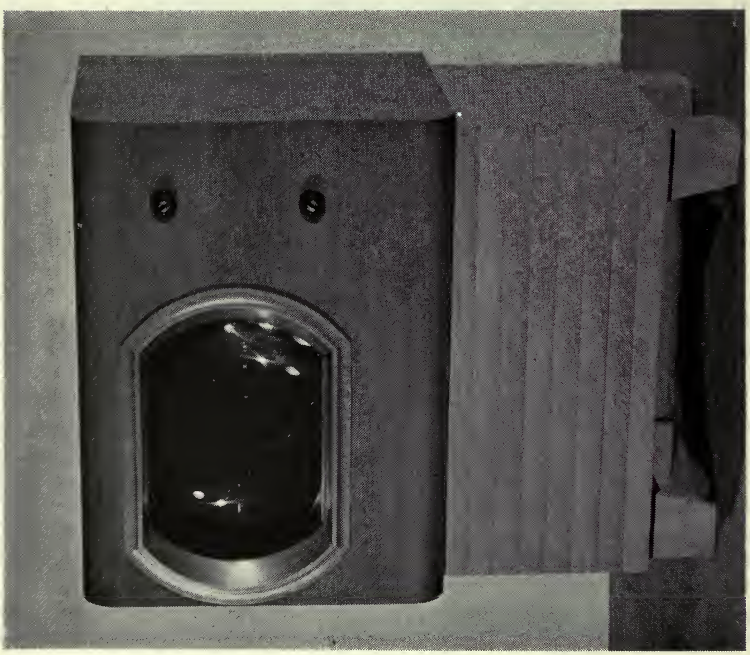


Fig. 15. Slave color receiver, front.

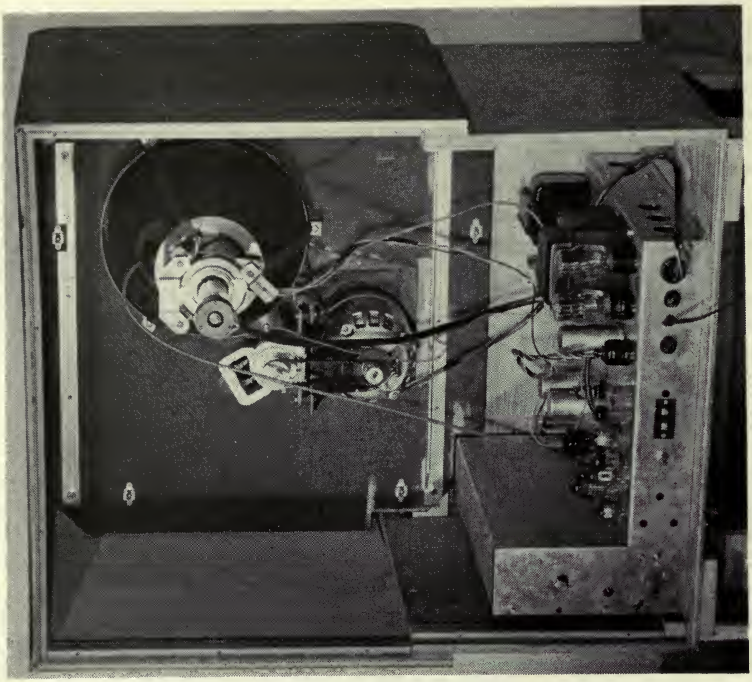


Fig. 16. Slave color receiver, back.

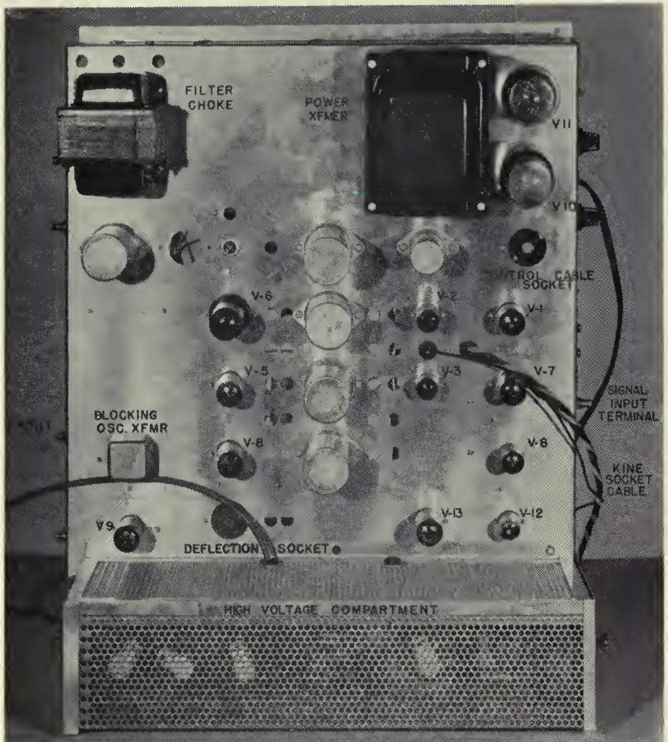


Fig. 17. Slave color receiver chassis, top.

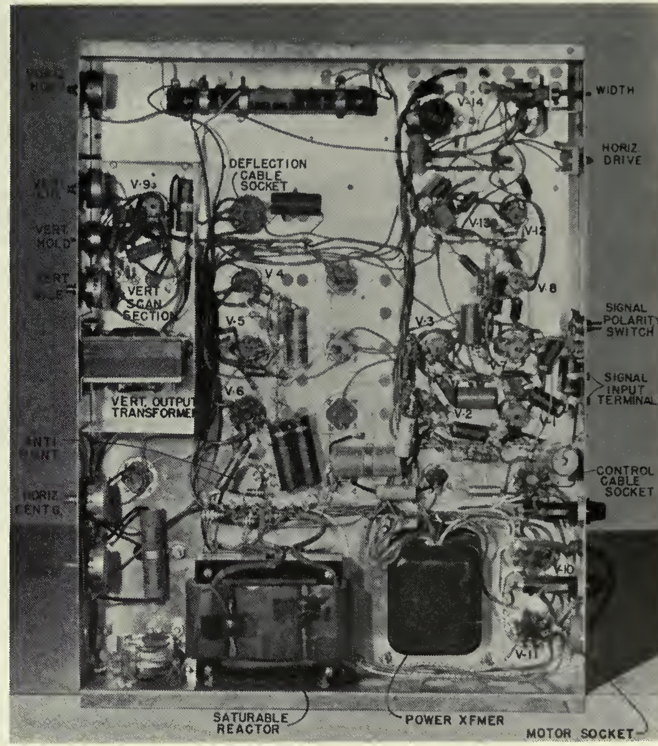


Fig. 18. Slave color receiver chassis, bottom.

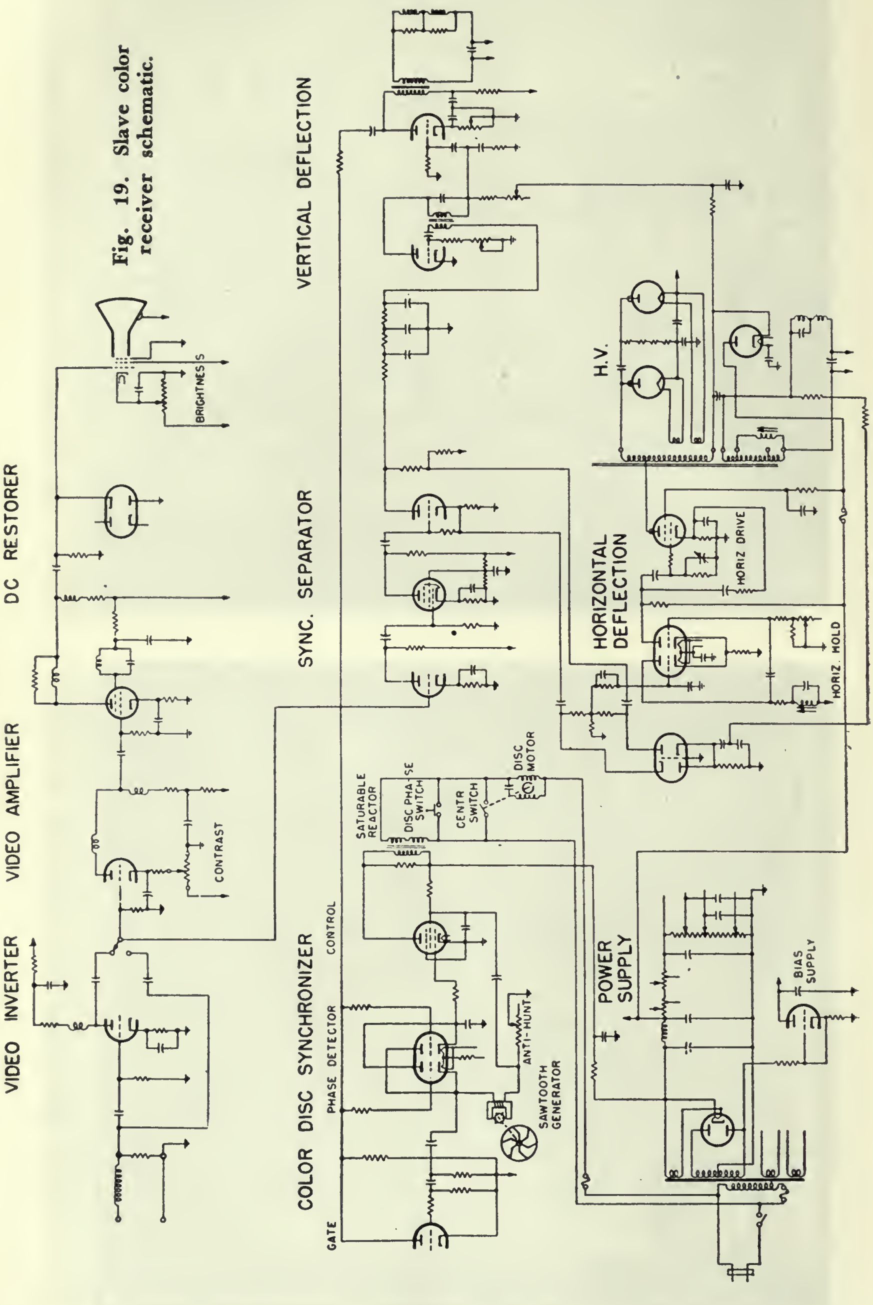


Fig. 19. Slave color receiver schematic.

monochrome sets to receive color. While adaptors may be used to permit reception of color broadcasts in black-and-white, and converters may be used to change these to color, a preferred method is that of using a slave color receiver. This unit scans at color frequencies only and presents a color picture by means of its own separate tube and color disk. It requires from the monochrome receiver only composite video. Sound is derived from the monochrome receiver in the usual manner. Since the slave receiver requires no RF, IF or audio stages, it is considerably less expensive than a complete color receiver.

The slave color receiver is shown in Figs. 15 and 16; the chassis is shown in Figs. 17 and 18; and its schematic is given in Fig. 19. Requirements for the various sections of this receiver are essentially the same as those described for the combination receiver. A few departures, however, are described in the following paragraphs.

Physical Characteristics. The overall dimensions of the slave color receiver are somewhat less than those of the combination receiver, being $27\frac{1}{2}$ in. wide by 33 in. high by 20 in. deep. Sixteen tubes are employed, including rectifiers.

Only a single chassis is used, the power supply and color disk drive components being arranged in such a manner as to produce no undesirable effects from their magnetic fields.

The lower of the two front panel knobs controls the off-on switch and the contrast. The upper knob is rotated to control the brightness and depressed to bring the color disk to the proper phase.

Video Circuits. Two stages of conventional design are employed. Video response is flat within 2 db from 30 cycle/sec to 4 mc with a voltage gain of approximately 115. A 4.5-mc sound trap in the 6AQ5 screen circuit provides 35-db rejection. A polarity reversal stage with unity gain provides operation with either polarity of incoming composite video. Since the contrast control is mounted at a distance from the chassis, a somewhat unconventional circuit is used in which a variable positive bias is applied to the cathode of the first video stage. With the constants used, this circuit gives adequate contrast range with negligible frequency discrimination.

Vertical Oscillator and Amplifier Circuits. To insure reliable interlace these circuits are placed in a shielded compartment. This eliminates interference from both nearby electrical fields and from the magnetic fields of the power transformer and saturable reactor.

III. CBS Color-Television Broadcast Facilities

Conversion of the RCA Monochrome Field Camera for Color Television

The first prototype conversion of the RCA Field Television Camera Chain was undertaken by the RCA Terminal Facilities Engineering Group in Camden, N. J., between May and July of 1950. Circuit changes and additions, which CBS had used satisfactorily in earlier color television equipment, were incorporated into several sections of the converted equipment. During 1950 a second and third camera chain were converted in the CBS General Engineering Department, incorporating improvements resulting from experience gained through use of the first equipment. These, and a few additional improvements, are now being incorporated in a new series of color camera chains, again using standard monochrome equipment as a basis.

In the first three conversions type TK-30A field camera chains with studio

Fig. 20. RCA monochrome camera converted for color, front view; lens turret removed and added color disk in place.

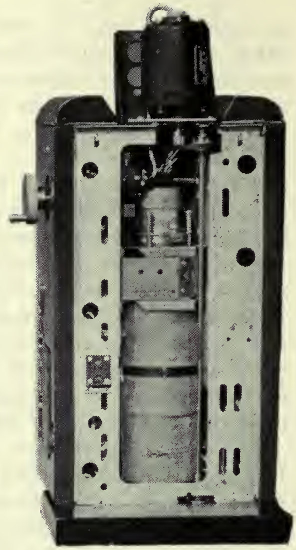


Fig. 21. RCA monochrome camera converted for color; top view, showing color drive assembly with added color-disk drive motor.

type RCA M126000 cameras were used. Figures 20 and 21 show how the color disk housing on these cameras is incorporated in a new front cover. Since the studio and field type cameras are identical as to circuit and chassis construction, the field camera with similar mechanical changes to the cover can also be successfully modified.

A block diagram showing the signal connections of a single camera chain, complete with synchronizing signal generator, is shown in Fig. 22. It will be noted that the connections are identical to those used for monochrome except for the addition of cables to the color mixer amplifier. The modifications necessary to each of the units shown in Fig. 22 will be described in some detail in the following sections.

Synchronizing Signal Generator Pulse Former. The principle changes to this unit are:

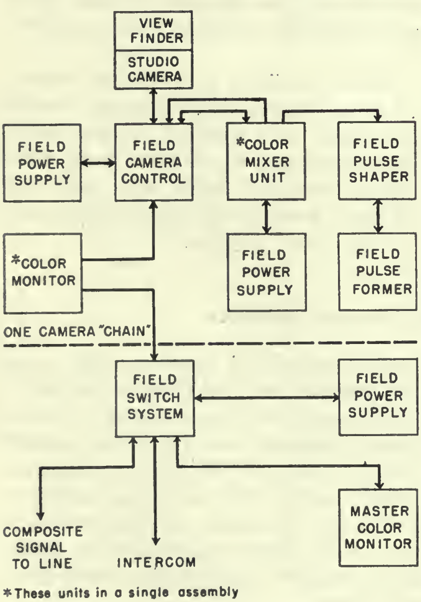


Fig. 22. RCA single camera chain converted for color, block diagram.

(a) Shift the master oscillator horizontal scanning frequency to 58,320 cycle/sec.

(b) Change the cathode bias resistors of the counters so that the first three counters count down 9-9-5 to give the 144-cycle/sec vertical triggering pulse, and the fourth counter counts down, 3 to 1, to give the color triggering pulse.

(c) Install three double triode miniature tubes on a small shelf mounted between terminal boards. These generate a color drive pulse and a color synchronizing pulse; both at a 48-cycle/sec rate. The color drive pulse is used for two purposes: first, to provide a trigger pulse for the color mixer red-gating circuit so that the red video channel is always properly identified (to be further described later); second, to provide a variable time delay to center exactly the timing of the color synchronizing pulse between the first and second equalizing pulses.

The color synchronizing pulse is introduced over an unused terminal and cable connection into the pulse shaper unit, where it is mixed with composite synchronizing signal.

The above describes an earlier method of generating a color synchronizing pulse, and while convenient it is not satisfactory when using step counters, since there is excessive time delay between the front edge of the original 58,320-cycle/sec trigger pulse and that of the 48-cycle/sec pulse from the fourth counter.

A more recent method is indicated in Fig. 23. A sufficiently wide color drive pulse, *b*, is generated to gate in only the first equalizing pulse of every third field. This single equalizing pulse, which does not shift in time phase, is used to trigger the color delay multivibrator. The resulting pulse is in turn differentiated and its trailing edge is used to trigger the color synchronizing pulse multivibrator. The width of the delay pulse thus controls the start of the color pulse generator, and the width of the color synchronizing pulse can then be adjusted to the required value of 0.04 H. The color synchronizing pulse should be properly centered between the first and second equalizing pulses by use of a trigger-time-base oscilloscope.

It is preferable to supply power for the filaments and the master oscillator lock-in from a small 144-cycle/sec generator driven by a synchronous motor. This avoids 60-cycle/sec phase modulation in the generated pulses due to poor filament grounds or common cathode-filament ground returns. Three miniature tubes on a small sub-chassis are used to generate a 60-cycle/sec comparison pulse for afc locking. This unit counts down 12 to 1 from the 720-pulse/sec output of the second counter. In some conversions a 4-to-1 and a 3-to-1 counter were used to obtain the 12-to-1 ratio with better stability. No problems were encountered in operating synchronizing signal generators expressly designed for color standards on a 60-cycle/sec power source.

Synchronizing Signal Pulse Shaper. In order to produce the pulse width required for the higher scanning speeds, *RC* changes are necessary in all the multivibrator pulse generating circuits. Pulse slopes with fast enough time-of-rise to meet FCC standards as shown in Fig. 1 can be obtained without difficulty. To inject the color synchronizing pulse directly into the synchronizing pulse mixing and clipping circuits, a small miniature tube is mounted on the chassis with its plate circuit connected in parallel with the composite synchronizing pulse mixing tubes.

Camera. Two major changes are required in the camera: (a) a new horizontal scanning circuit to supply the higher scanning power necessary for camera tube deflection; and (b) the addition of the color disk to the front end of the camera with accompanying

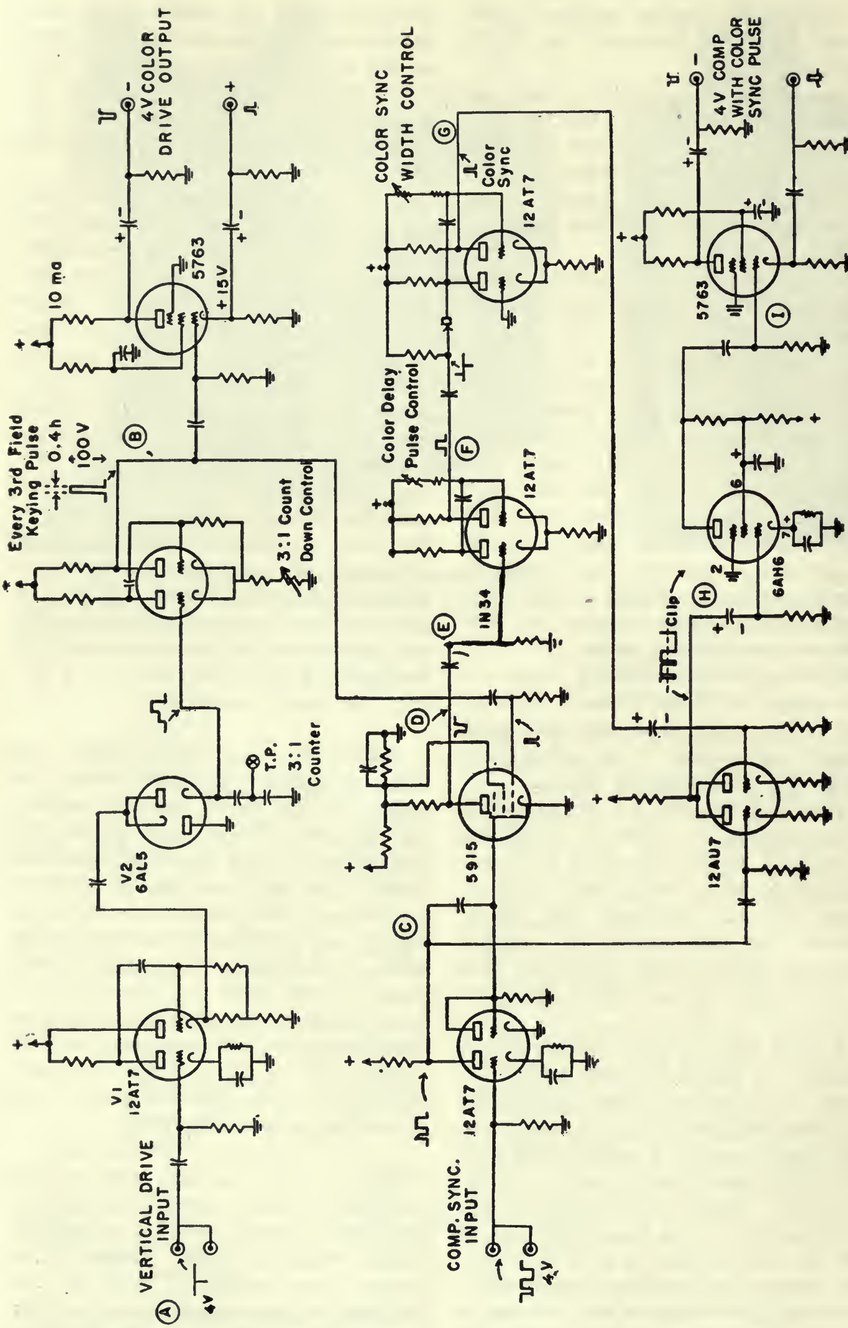

A
VERTICAL DRIVE INPUT
4V
V1 12AT7
V2 6AL5
T.P.
3:1 Counter
3:1 Count Down Control
Every 3rd Field Keying Pulse
0.4h
100 V
B
10 ma
5763
+15V
4V COLOR DRIVE OUTPUT
C
COMP. SYNC. INPUT
4V
12AT7
5915
D
E
1N34
12AT7
F
Color Delay Pulse Control
COLOR SYNC WIDTH CONTROL
G
Color Sync
12AT7
12AUT
CLIP
H
6AH6
I
5763
4V COMP WITH COLOR SYNC PULSE

Fig. 23(a)

mechanical modifications of the focusing mechanism.

The horizontal scanning circuit used in the second and third conversions has proved entirely reliable in extensive use in industrial color camera equipment. This circuit is shown in Fig. 24. The normal output transformer is replaced with a specially designed transformer using grooved textolite and formex forms placed over dual three-mil laminated hypersil cores.

Instead of the +360-v unregulated source normally used, the damping tube is used to provide a rectified boost voltage. This avoids any 120-cycle/sec ripple component that might cause a 24-cycle/sec phase jitter in the horizontal scanning. As in black-and-white service, a scanning current of 1 amp peak-to-peak is normally required. This circuit, however, is capable of supplying a linear scanning current of 1.3 amp peak-to-peak, which allows sufficient overscanning to prevent burn-in of the mask on the target.

Installation of the color disk drive assembly requires that the lens turret and light trap be moved forward and that the front face plate of the camera be replaced. To permit all lenses to be focused to infinity, the back edge of the camera tube bakelite mask retainer ring is undercut by approximately $\frac{1}{8}$ in. This allows the tube to be pushed sufficiently forward into the focus coil assembly.

The color disk, which rotates at 720 rpm, is mounted directly on the end of a $\frac{1}{4}$-in. shaft which extends lengthwise through the top portion of the camera and runs in oilite sleeve bearings mounted on the new front face plate and the rear of the camera chassis. At one end of the shaft is mounted a twelve-tooth sprocket which is coupled to a six-tooth sprocket on the motor by means of a Gilmer timing belt (mold No. 9164). The motor is a one-hundredth horsepower salient pole synchronous type (Cyclohm model No. SWC2914-XL). It operates from a 48-cycle/sec, 115-v, 25-w amplifier located in the color mixer chassis. This arrangement permits continuous electrical phase adjustment. Proper phase adjustment occurs when the spokes of the disk, separating adjacent color filters, coincide with the locus of the scanning beam in the camera tube. This condition is necessary in order to avoid color carry-over from one field to the next. Since the optical image is inverted on the photocathode and the raster is therefore scanned from bottom to top, it follows that the disk, as viewed in Fig. 20, must turn clockwise. To meet the colorimetric requirements discussed previously in this paper, No. 25 red, No. 47, half-density blue, and No. 58,

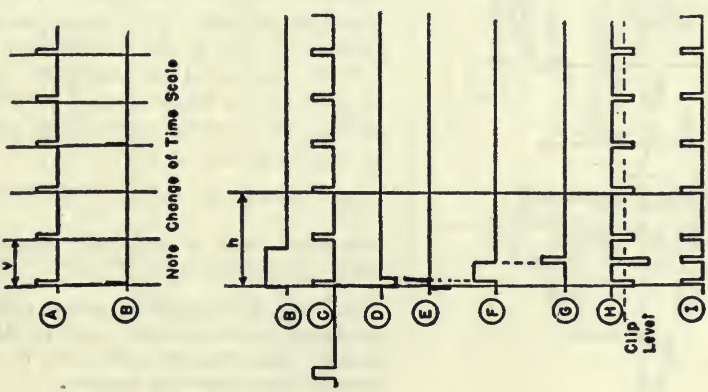
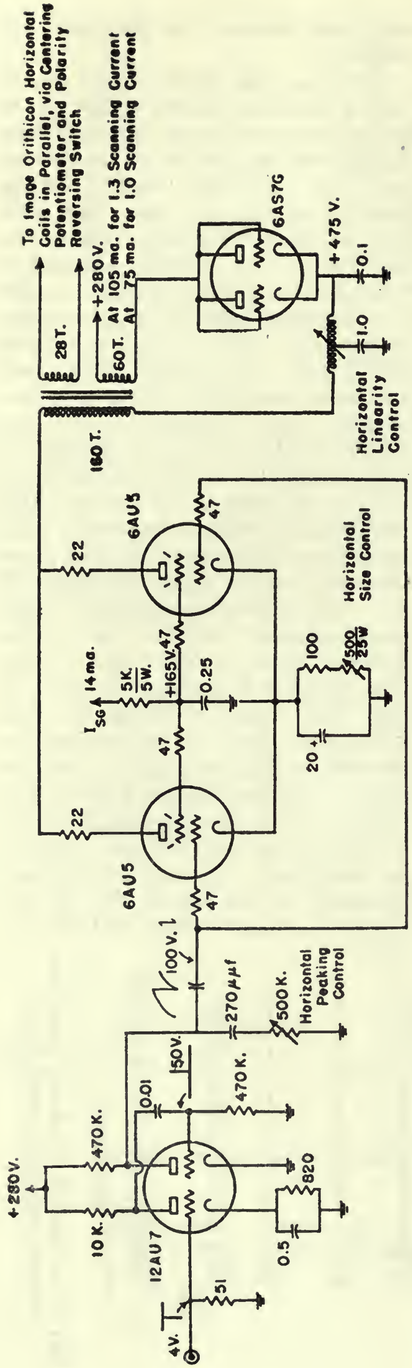


Fig. 23(b)

Fig. 23. A method of adding color sync pulse to composite sync signals.



three-quarters density green color filters are used.*

Camera Viewfinder. The circuit modifications in the viewfinder are of a minor nature, mostly involving *RC* changes. The original deflection yoke and transformer may be retained if the horizontal coils of the yoke are reconnected in parallel in order to obtain a sufficiently fast retrace. This is required since the narrow image-orthicon target blanking derived from the vertical and horizontal driving pulses is used for blanking of the picture tube in the viewfinder.

Camera Control Unit. In this unit it is necessary to:

(a) Substitute a 7RP4 picture tube for the 7CP4. This provides a brighter picture as is desirable for monitoring in color;

(b) Add a high-voltage supply of at least 10,000 v (for the 7RP4 picture tube);

(c) Modify the horizontal scanning circuit;

(d) Provide mechanical modifications necessary to mount the new tube in place; and

(e) Move the front panel controls to provide space for a color disk and its enclosure in front of the picture tube.

Not all of these changes are necessary if the original 7CP4 picture tube is used as a monitor in black-and-white (color standards without color disk). In this case it is advisable to include a picture monitor in color in the color mixer.

With this latter arrangement, i.e., black-and-white monitoring of the color picture, the camera control unit need be modified only as follows:

(a) Connect the output of the fourth

---

* Numbers refer to published transmittance characteristics for Wratten filters.

Fig. 24. Horizontal scanning circuit for image orthicon tube used in RCA camera converted for color and in industrial color television camera.

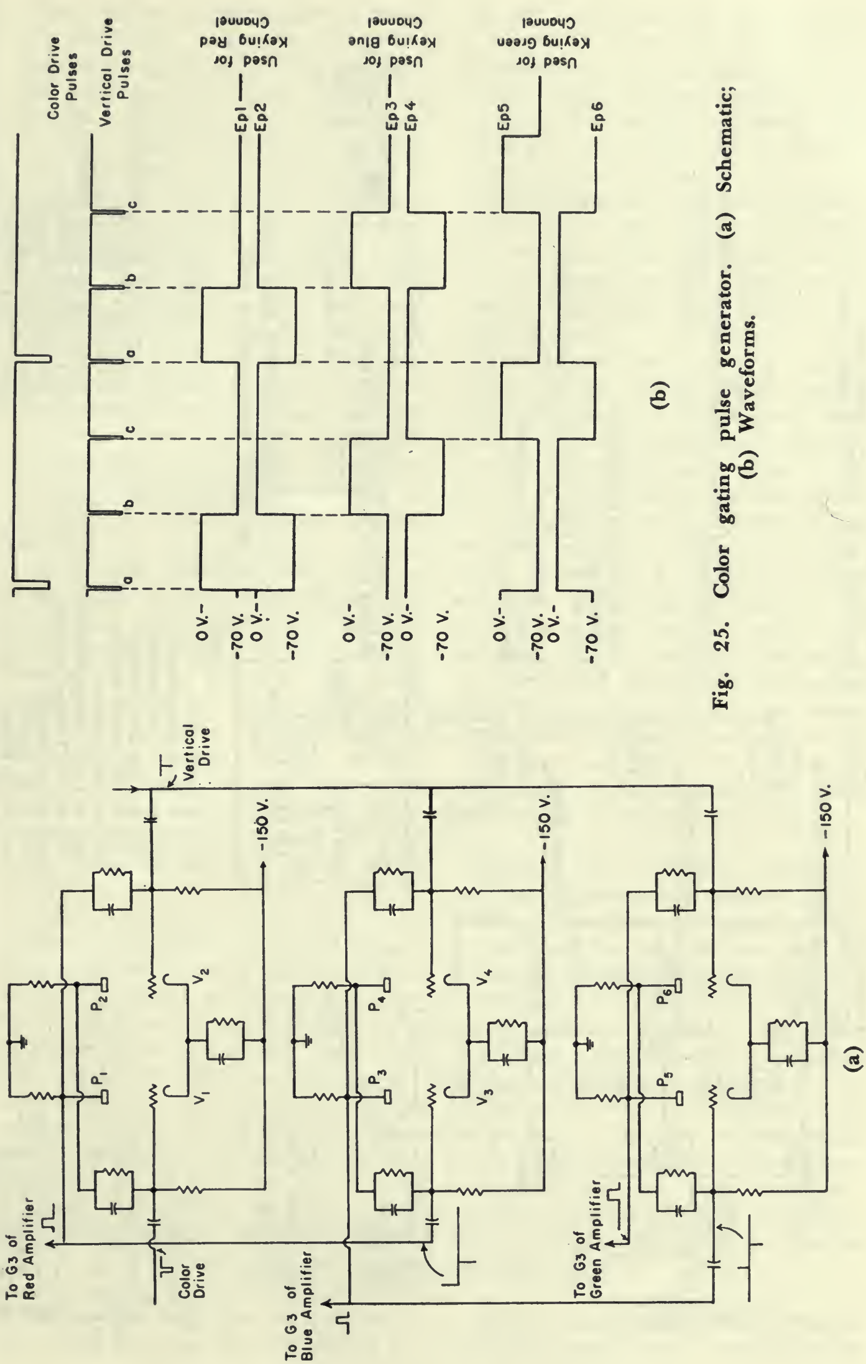


Fig. 25. Color gating pulse generator. (a) Schematic; (b) Waveforms.

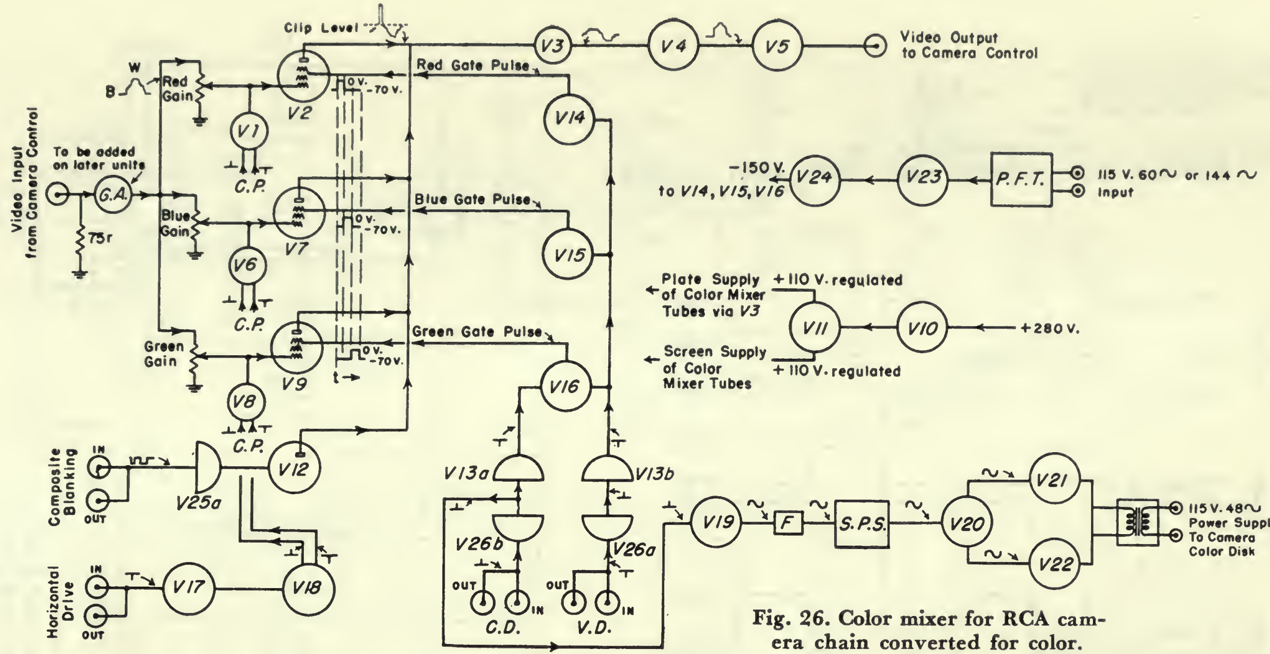


Fig. 26. Color mixer for RCA camera chain converted for color.

Legend:

C.D. = color drive
C.P. = clamp pulses
F. = filter
G.A. = gamma amplifier
P.F.T. = power and filament transformer
S.P.S. = selsyn phase shifter (continuous rotation)
V.D. = vertical drive
V1 = 6AL5 diode clamper
V2 = 6AU6 red amplifier
V3 = 6AL5 clipper
V4 = 6AC7 amplifier
V5 = 6AG7 output
V6 = 6AL5 diode clamper
V7 = 6AU6 blue amplifier
V8 = 6AL5 diode clamper
V9 = 6AU6 green amplifier
V10 = OB2 regulator
V11 = 12AT7 voltage regulator
V12 = 12AT7 clipper amplifier
V13a = 6J6 amplifier
V13b = 6J6 amplifier
V14 = 6J6 flip-flop
V15 = 6J6 flip-flop
V16 = 6J6 flip-flop
V17 = 12AT7 amplifier
V18 = 6AQ5 output
V19 = 12AU7 square wave generator
V20 = 12AT7 amplifier
V21 = 6L6 push-pull
V22 = 6L6 push-pull amplifier AB_2
V23 = 6X5GT rectifier
V24 = VR150 regulator
V25a = 12AT7 amplifier
V26a = 12AT7 amplifier
V26b = 12AT7 cathode follower

video stage to an output jack by means of a 6AG7 tube with a low-impedance plate coupling circuit. The signal from this point may be passed through an external connection to a color mixer, for color mixing and injection of blanking. The signal is then returned to an input jack on the control unit, where the signal is further amplified in the normal manner. Since blanking is not used in this camera control unit, tube V8 can be removed and the additional 6AG7 tube can be installed in its place.

(b) Parallel the horizontal yoke coils and install a new horizontal output transformer of the type used in color receivers. These circuits should be powered from the regulated d-c supply. The boost winding should be used to provide the additional plate voltage required.

(c) Provide a definite color sequence presentation on the waveform monitor so that both the amount of red, blue and green video signals and the blanking constants can be observed and individually adjusted. The 48-cycle/sec color drive pulse can be applied to the synchronizing circuit of the vertical sweep, preferably through tube V6, connected as a cathode follower. This provides the necessary isolation to prevent kickback into the color drive circuits.

Color Mixer Unit. One color mixer unit is added to each camera chain. Its main purpose is to channel the video signal into three separately adjustable amplifiers, each amplifying only one color and each being turned on sequentially, i.e., when the image is televised through the red filter, the video signal is amplified only in the red video channel.

Figure 25 illustrates the color-gating pulse generator which controls the operation of the color mixer. A functional block diagram of the color mixer is shown in Fig. 26. The color mixer—front view and rear view—is shown in Fig. 27. This unit with cover removed is shown in Fig. 28. In this unit composite receiver blanking is injected in the normal manner, clipped, amplified and if so desired, returned to the camera control unit for further addition to synchronizing signals.

For the accurate rendition of delicate color shades a gamma correction amplifier is incorporated to compensate for the compressed black output of the typical kinescope (light output vs. signal output).

The 48-cycle/sec, 115-v power required by the camera disk motor is derived as follows: The color drive pulse actuates a multivibrator to generate a 48-cycle square wave, which is converted to a sine wave by filtering out all harmonics above 48 cycles. The resultant signal is coupled through a selsyn motor to a push-pull output amplifier. A standard 5000-ohm output transformer is used to couple the amplifier to the camera disk motor. As mentioned previously, the selsyn permits convenient and accurate adjustment of the color disk phase with respect to camera scanning. The circuit arrangement for the camera disk motor power supply is also shown in Fig. 26.

Regulated Power Supplies. Originally, additional filtering was required on the +360-v unregulated terminal since power from this terminal was used for horizontal camera scanning. In later conversions, however, only the horizontal scanning circuit of the viewfinder is operated from this terminal and the horizontal camera scanning is connected to the regulated source. If a slight amount of 120-cycle/sec ripple in the 360-v terminal causes interference in the horizontal scan of the viewfinder, a small 4-h, 80-ma, choke in conjunction with a 10-microfarad, 600-v capacitor will prove helpful.

General Considerations. No difficulty should be experienced in operating the

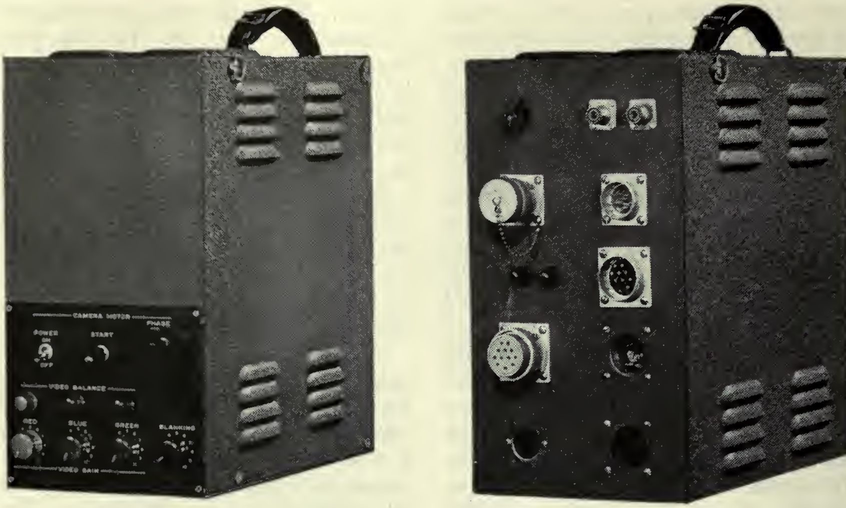


Fig. 27. Color mixer for RCA camera chain converted for color, front view and rear view.

Fig. 28. Interior of unit of Fig. 27.

Fig. 29. Studio 57 stage with two color cameras.

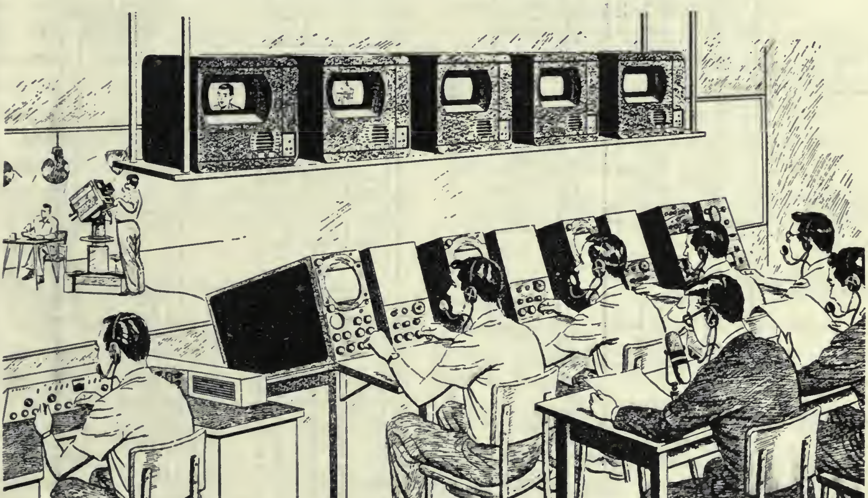
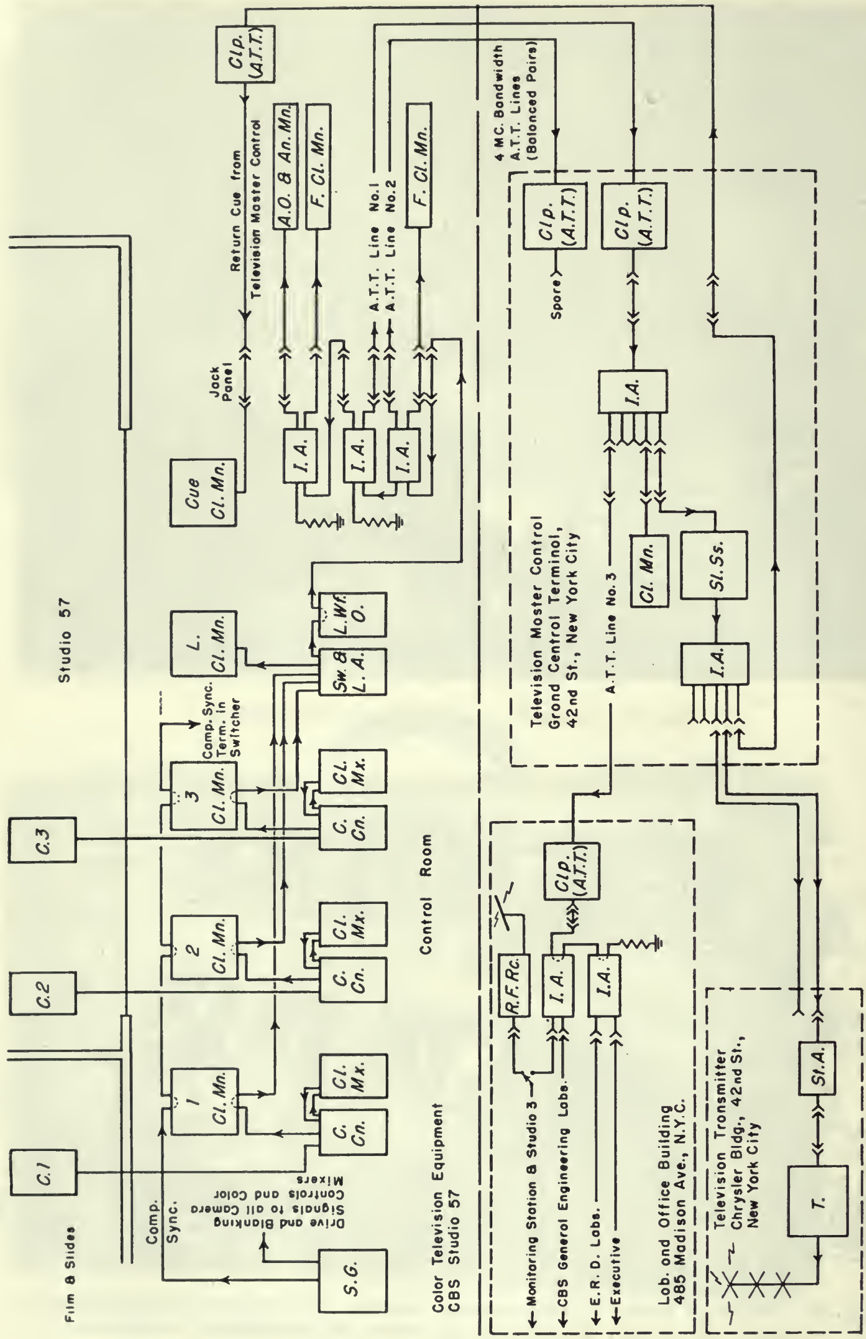


Fig. 30. Sketch of Studio 57 control room showing the director, assistant director, technical supervisor, monitoring operators and monitoring equipment.



Studio 57
Film & Slides
C.1
C.2
C.3
Comp. Sync.
S.G.
Drive and Blanking Signals to all Camera Controls and Color Mixers
Cl. Mn.
C. Cn.
Cl. Mx.
Comp. Sync. Term. in Switcher
Sw. & L. A.
L.W.F. O.
L. Cl. Mn.
Cue Cl. Mn.
Jack Panel
I. A.
Return Cue from Television Master Control
Clp. (A.T.T.)
A.O. & An. Mn.
F. Cl. Mn.
A.T.T. Line No.1
A.T.T. Line No.2
Control Room
Color Television Equipment CBS Studio 57
4 MC. Bandwidth A.T.T. Lines (Balanced Pairs)
Spare
Television Master Control Grand Central Terminal, 42nd St., New York City
A.T.T. Line No. 3
Sl. Ss.
R.F. Rc.
Monitoring Station & Studio 3
CBS General Engineering Labs.
E.R.D. Labs.
Executive
Lab. and Office Building 485 Madison Ave., N.Y.C.
St. A.
T.
Television Transmitter Chrysler Bldg., 42nd St., New York City

Fig. 31. Color television signal distribution system, block diagram.

A.O.&An.Mn.	=	audio operator, announcer and monitor
C.	=	camera
C.C.N.	=	camera control
CL.MN.	=	color monitor
CL.MX.	=	color mixer
CLP.	=	clamper
COMP.	=	composite
F.CL.MN.	=	floor color monitor
I.A.	=	isolation amplifier
L.WF.O.	=	line waveform oscilloscope
L.CL.MN.	=	line color monitor
RC.	=	receiver
S.G.	=	sync generator
SL.SS.	=	selector system
SW. & L.A.	=	switcher and line amplifier
ST.A.	=	stabilizer amplifier
T.	=	transmitter

entire camera chain from a 60-cycle/sec source if a synchronizing signal generator originally designed for color television is used and if common cathode-filament leads and all inadequate ground leads are eliminated. As an alternative, a synchronized 144-cycle/sec motor generator can be used to power all filaments and the synchronizing generator shaping units. A 1500-w unit is adequate for a two-camera chain.

The inter-lock circuits should be so connected that the regulated supplies of the two chains can be turned on only if the separate power input for the filament transformer is energized (with either a 60- or 144-cycle/sec, 115-v source).

Identical procedures to those used in monochrome may be employed in operating and adjusting the camera control and tube voltages of the color chains.

Film and Slide Scanning Equipment

One method of color film scanning has been described in detail in this JOURNAL.[4] Another method makes use of an intermittent-type motion picture projector to project the color film through a shutter directly onto the image-orthicon photocathode.

The projector is a monochrome type used for 16-mm film at 24 frame/sec. The projector is driven by a synchronous motor and is thereby locked to the 144-cycle/sec field rate of the color system. Between the projector lens and the color camera a light shutter rotates which has a multiple of three slots. If the shutter rotates at 48 rev/sec, three slots are required, and the width of each slot is such that the duration of exposure is less than the vertical blanking time. This shutter is also driven by a phaseable synchronous motor. The proper red, blue and green color filters cover the shutter openings, and the projector and shutter disk are so phased with respect to the camera scanning that successive red, blue and green color images are flashed onto the camera tube photocathode only during vertical retrace times. The pulldown time of the projector is of short enough duration so that the film moves 24 times/sec only during portions of the active scanning period. In that period, however, the light from the projector is cut off by the opaque sections of the slotted disk.

Two methods have been used to scan color slides. One, using an image-dissector tube, has been described,[4] together with the film scanning method. In this arrangement the slide projector and its color disk replace the film scanner; the images are projected directly onto the photocathode of the dissector tube.

The second method consists simply of projecting the color slides at low light intensity directly into a conventional image orthicon-equipped color television camera.

Studio Lighting for Color Television

In general, flat lighting over the entire stage area gives best results for color television. A certain amount of modeling may be desirable, in which case ordinary spotlights are satisfactory.

---

[4] Bernard Erde, "Color television scanner," *Jour. SMPE*, vol. 51, pp. 351–372, Oct. 1948. This scanner uses an image-dissector tube and continuously moving film.

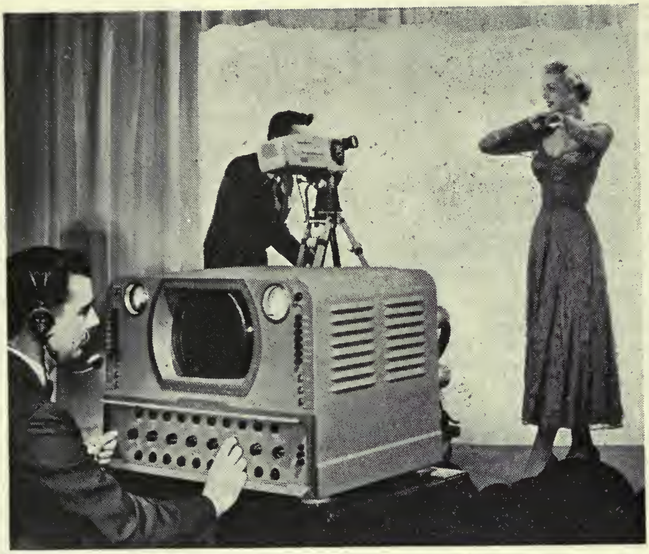


Fig. 32. Industrial color television equipment; camera and control console.

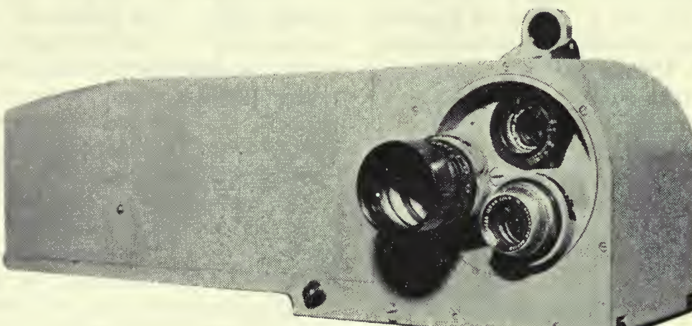


Fig. 33. Industrial color television camera, front view. Tripod not shown.

For overall flat key lighting 3500 K (white) fluorescent lighting is excellent. The advantages of this type of key lighting are that it contains no infrared, is relatively shadowless, generates little heat and is relatively efficient. The fluorescent lamps for key lighting can be operated from a standard three-phase 60-cycle/sec supply but must be connected in such a manner that all three phases are represented in any three adjacent bulbs.

Spotlights for modeling should be infrared corrected. This can be accomplished by means of one-inch strips of Aklo No. 3962 glass (or equivalent) placed in front of the spotlight. The strips prevent the Aklo filter from cracking with absorption of radiated heat.

If incandescent lighting with a color temperature of 2900 K is used, it is advisable to provide infrared filtering by using an Aklo No. 3962 (polished) glass filter between the camera lens and image-orthicon tube. Since each Aklo

filter attenuates the visual spectrum by approximately 50%, it is preferable, when possible, to employ the newly developed interference heat filters. One type already tested, known as type EK-227, passes the visual range with an efficiency of almost 90%, while the infrared energy is attentuated by 91%.*

Standard photofloods furnish satisfactory lighting for color studio use, but naturally are short lived. In most cases infrared filtering is not required with this type of lighting. Lamps used in clusters and floor strips provide an excellent source of light. These have color temperatures of approximately 3200 K and require only mild infrared correction.

As to light level requirements, experience has shown that 200 ft-c (foot-candles) infrared-corrected incident light will permit sufficient stopping down of the camera lenses to provide an adequate depth of focus. On the other hand, an $f/2$ lens and 20 ft-c of corrected incident light will produce an acceptable color picture.

Figure 29 shows two color cameras in operation in CBS Studio 57. The left camera takes long shots while the camera on the right is used for close-ups.

Figure 30 is a sketch of the control room. In the upper portion are shown the color monitors, one each for the live cameras, slide projectors, film cameras, and one for monitoring the outgoing picture. The operator at the extreme left controls the audio console; the next three operators control the video. Each of these also operates a color mixer in order to assure optimum color fidelity. The remaining indicated personnel are the director, the assistant director and the technical supervisor.

Figure 31 is a block diagram of the video signal distribution system. Each camera has an associated camera control, a color mixer and a color monitor. Several color monitors are used to permit program cuing, timing and overall checking.

The outgoing signal is transmitted over video lines of the telephone company from Studio 57 at 109th Street and Fifth Avenue to TV Master Control at Grand Central Terminal in New York City. From there the signals are distributed to network stations and to the WCBS-TV television transmitter in the Chrysler Building.[5]

*If the infrared sensitivity of image-orthicon tubes were sufficiently low, it would be possible to dispense with infrared filters.

IV. Industrial Color Television

Since the advent of industrial television, its uses have expanded enormously, and with the addition of color there seems to be no limit to the number of applications it will satisfy in science, medicine, education, industry and government. Industrial equipment is essentially closed-link equipment designed with emphasis on ruggedness and reliability. Such equipment, designed by CBS, is now available and is marketed by Remington Rand under the trade name "Vericolor."

Figure 32 shows the industrial color camera with its control console. Since it is desirable to reduce camera weight and size to a minimum, the camera control equipment, synchronizing signal generator, waveform monitoring, etc., are all located in the control console. The color monitor in the console and the optical viewfinder at the camera take the place of a color viewer at the camera.

[5] W. R. Fraser and G. J. Badgley, "Motion picture color photography of color television images," *Jour. SMPTE*, vol. 54, pp. 735–744, June 1950. Motion picture color photography of color television images has been successfully accomplished and is described in the literature.

Fig. 34. Monochrome and industrial color television cameras.

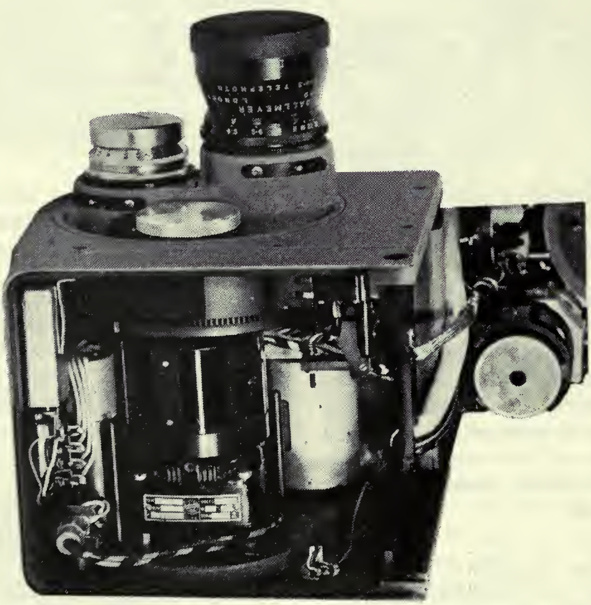


Fig. 35. Industrial color television camera with color-disk drive.

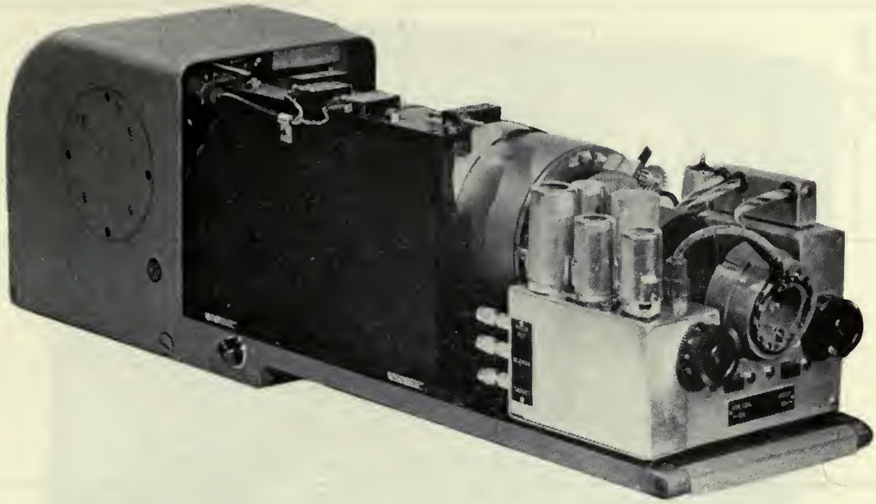


Fig. 36. Industrial color television camera with preamplifier, dynode power supply, and image orthicon focus and alignment coils.

The industrial color camera (exclusive of the tripod) weighs only 43 lb. As illustrated in Fig. 33, it is unusually compact, being only 23 in. long by $7\frac{1}{2}$ in. by $7\frac{1}{2}$ in. Figure 34 is a comparison photograph of the RCA monochrome television camera and the CBS industrial color television camera. Figures 35 and 36 are interior views of the industrial color television camera.

Camera focusing and lens selection are remotely controllable from the control console. Any one of three lenses in the turret may be selected by pressing the corresponding button. Full focusing range control is provided for the 83-mm and the 135-mm lenses; for the 9-in. lens two lens-shifting steps of 1-in. each are provided on the camera turret in conjunction with a remotely controlled continuous travel range of $1\frac{1}{2}$ in.

A small synchronous motor operating at 1440 rpm drives the $2\frac{1}{2}$-in. diameter color filter drum.

The output voltage of the camera in normal use is approximately 0.3 v peak-to-peak. This is derived from a self-contained preamplifier. The first two tubes in this unit function as normal wide-band amplifiers with a small amount of degeneration in the cathode circuits; the output stage is a conventional triode cathode follower. A compact 3-kc, 1500-v supply with its voltage divider furnishes all the voltages required by the image orthicon tube. A 25-ft cable connects the camera to the control console.

This color camera has proved to be extremely valuable for live pickup in color at low illumination levels. Acceptable color images can be obtained with only 45 ft-c of incident 3500 K fluorescent light and a lens opening of $f/3.5$. With incident light of 100 ft-c excellent picture quality is obtainable.

The Control Console

Figure 37 is a block diagram of the complete equipment. The signal leaving the color camera passes through the camera cable to the console (shown in Fig. 38) where the following functions are performed (the rear of the console is shown in Fig. 39):

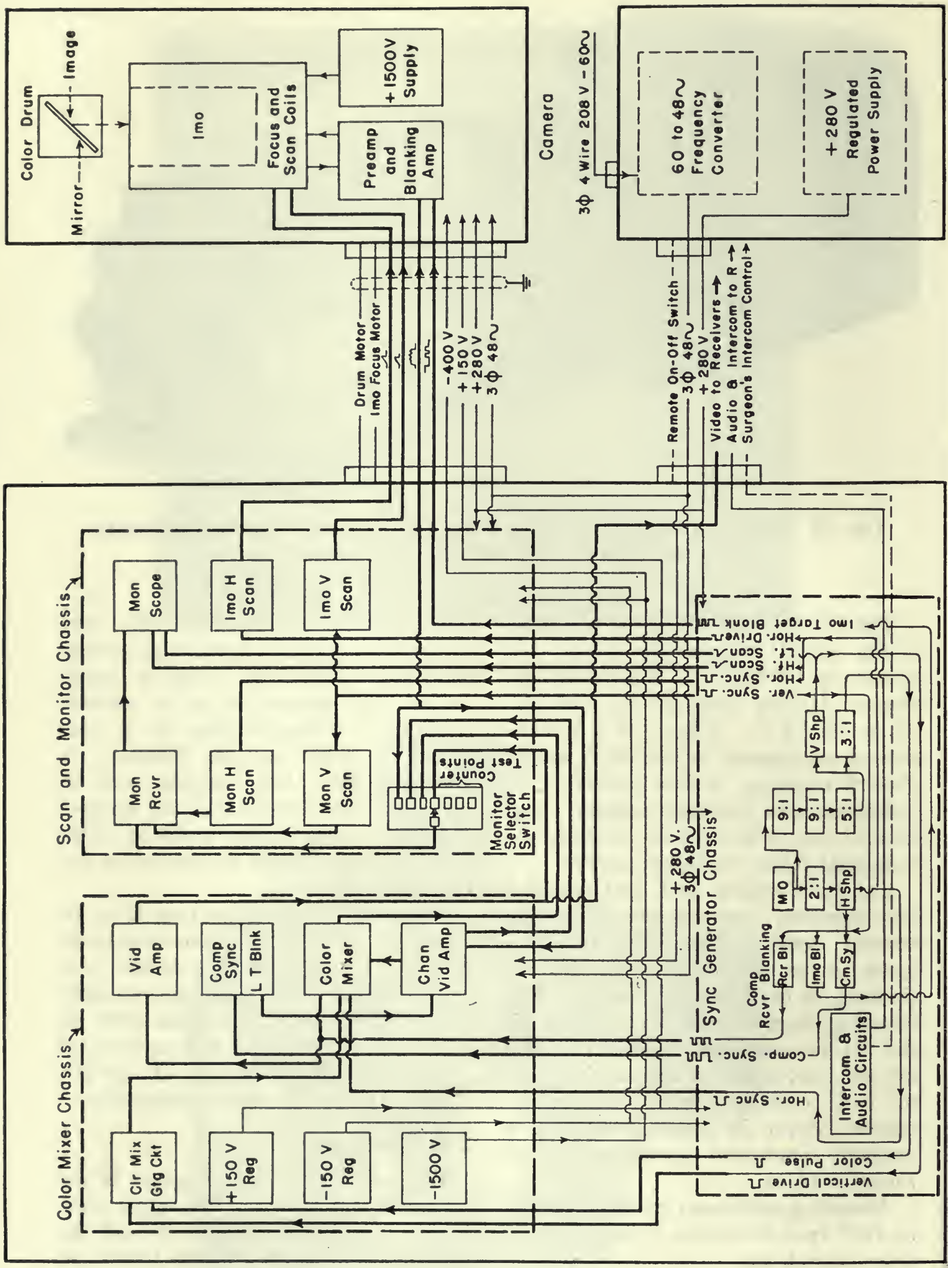


Fig. 37. Industrial color television equipment, block diagram.

Fig. 38. Industrial color television monitor console (cover closed). Note—The oscilloscope in the upper right corner shows red, blue and green signals.

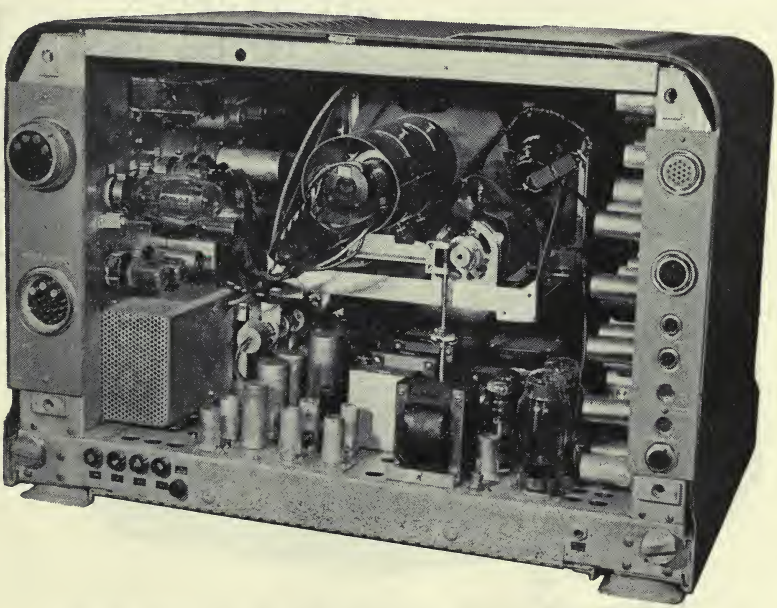


Fig. 39. Rear view of Fig. 38 showing 3-chassis construction.

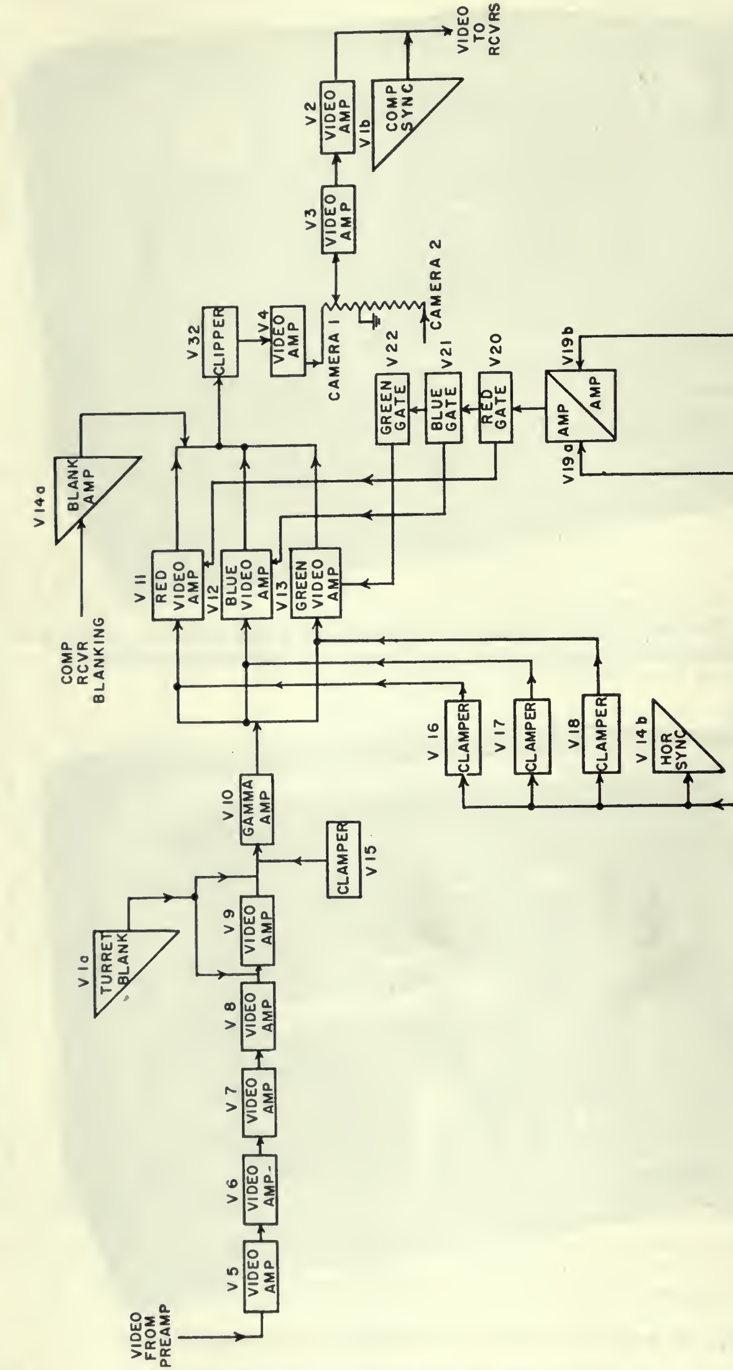


Fig. 40. Color mixer and related circuits, block diagram.

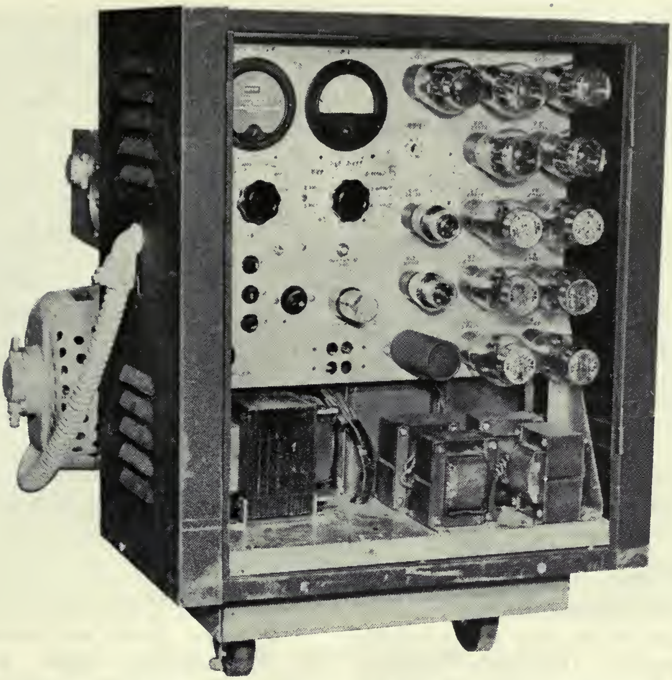


Fig. 41. Frequency converter and power supply regulator.

Fig. 42. Industrial color television monitor.

(1) amplification of the video signal;

(2) reinsertion of the high frequencies lost in the camera, the connecting cable, and the input circuit of the console;

(3) electrical separation of the video signals representative of the three colors in the color mixer so that each may be controlled independently as to brightness and video level (color mixer);

(4) recombining the controlled video signals;

(5) amplification and mixing of the synchronizing pulses with the video signal;

(6) remote control of camera focus;

(7) remote control of camera lens selection; signal automatically blanked during motion of the lens turret; and

(8) complete color picture monitoring of the outgoing signal.

General Circuits

Figure 40 is a block diagram showing the functions of the color mixer and its related circuits. The video amplifier consists of five tubes, V5 to V9. It is of conventional design with a bandwidth of 10 mc. A conventional equalizing circuit is located in the plate load of the first stage. Tube V1 is used to generate a blanking signal which momentarily blanks the video amplifier at V8 and V9 whenever the turret selection button is pressed. Tubes V11 to V13, inclusive, and V15 to V18, inclusive, operate as conventional clampers in maintaining the desired black level during the blanking signal period.

Color Mixer

The signal from V9 is coupled to a gamma control amplifier, the output of which is branched into three identical amplifiers. A gain control is located at the input of each of these units. Gating is performed by a rectangular wave of 1/144-second duration at the color repetition rate (48 cycle/sec) which originates in the ring circuit to be discussed later. In the circuit shown, tube V11 is the amplifier for red, V12 for blue, and V13 for green, each tube controlling only one primary color. Composite blanking, the amplitude of which may be adjusted, is superimposed on the plates of these tubes. The output is amplified and coupled into a voltage divider, which is used as an output gain control. Finally, after passing through two video amplifier stages, the video signal is mixed with the synchronizing pulses to form the final output signal.

Pulse shapes and relative phases from the gating ring circuit are shown in Fig. 25.

Sweep Circuits

The sweep circuits for both the image orthicon and the monitor color tube are of orthodox design with the exception of the special horizontal output transformers used.

Audio Equipment

The audio circuits are mounted on the synchronizing signal generator chassis. They provide amplified intercommunication between the video operator, camera man, director, and remote locations such as classrooms in other buildings. A control tube, V31B, acts as a remotely controlled switch, allowing extra earphones to be connected across the intercommunication circuit. If, for instance, a medical student watching an operation in a classroom wishes to ask a question of the surgeon in the operating room, he pushes a button located on the intercommunication headset at the color receiver. This connects the surgeon's hearing-aid-type earpiece across the intercommunication circuit. The surgeon answers the question over the regular program channel, using a miniature microphone in his mask.

The audio circuits in the console also provide amplification of the audio program. A two-channel microphone input and +8VU level balanced output are provided. These can accommodate the surgeon's microphone and two additional microphones.

Fig. 43. Industrial color television monitor chassis.

Power and Control Circuits

To effect an overall simplification of the equipment, 48-cycle/sec power is obtained from a motor-generator set, shown in Fig. 41, operable from a 60-cycle/sec, 3-phase, 4-wire 208-v supply. Two hundred eighty volts d-c at 1 amp is obtained from a conventional regulated power supply which is mounted with the motor generator on a portable assembly.

A switch on the console remotely controls power to the entire equipment. Power for field excitation of the motor generator is applied approximately twenty seconds after the main switch has been closed by means of a time-delay relay.

Maintenance and operational checks are facilitated by both a meter on the regulated supply and test connections at the motor generator.

Color Monitor

Figure 42 is a photograph of a color television industrial monitor showing an intercommunication handset recessed at the left rear of the console. Figure 43 shows the chassis construction and arrangement of this unit.

Acknowledgment. This paper in many ways is intended as a tribute to that handful of tireless and enthusiastic workers, namely, the people of the CBS Laboratories Division, who helped to develop the CBS color television system from its modest start in the spring of 1940 up to the time it became the national color television standard after gruelling hearings and exhaustive comparative tests.

To the management of CBS we express our appreciation for their never-failing faith in our work. Without their generous and courageous support this new industry would not have been born.

A New Technique for Improving the Sharpness of Television Pictures

By PETER C. GOLDMARK and JOHN M. HOLLYWOOD

In conjunction with the CBS color television system a method has been developed for improving the apparent picture definition, called "crispening." It uses nonlinear circuitry to decrease the apparent rise time of an isolated step input which is applied to a bandwidth limited system. This gives the color television pictures (with the exception of repetitive patterns representing frequencies beyond system cutoff) the appearance of having been transmitted through a system of greater bandwidth. The basic idea is to add to a waveform with a slow transition a second waveform, representing the difference between the desired waveform and the original waveform.

A simple circuit is described which utilizes nonlinear means for reforming the roughly triangular differential of the step signal into a narrower "spike" roughly triangular in shape which is superimposed on the original waveform to obtain a response corresponding to about half the original rise time. Various crispening circuits have been designed for specific applications and will be discussed in more detail.

When viewing television pictures, the observer trying to follow the action has little time to delve into any particular area of the picture and focus his attention on any one fine detail, unless the detail is stationary and of some special importance. Nevertheless, an observer will always be able to tell whether a picture is sharp or fuzzy. Experience has shown that pictures appearing sharp do not necessarily contain extremely small objects, objects so small that they require the ultimate bandwidth of the system. It is the sharpness of objects almost always greater than one or two picture elements which matters, and the purpose of this paper is to report on a method rendering outlines of such objects sharper, corresponding to, roughly, double the bandwidth.

The overall impression of such a picture with sharper outlines can be called crisp. The special circuits capable of obtaining such an appearance with a limited bandwidth, have been called crispening circuits.

A contribution submitted September 4, 1951, by Peter C. Goldmark and John M. Hollywood, Laboratories Division, Columbia Broadcasting System, Inc., 485 Madison Ave., New York 22, N.Y. This paper is being published simultaneously in the *Proceedings of the I.R.E.*

In the CBS field-sequential color television system the horizontal resolution is a little over half that of standard monochrome television. In the technique to be described, outlines of objects wider than a single picture element can be made as sharp as the maximum sharpness possible in standard monochrome pictures as far as the horizontal direction is concerned. Naturally, due to the 4-mc video limitation, the smallest object which the color system now can depict accurately in a horizontal direction is equivalent, roughly, to two monochrome picture elements. It is seldom, however, that the overall sharpness of a picture depends on being able to depict such small objects accurately. In fact, in such cases, by the choice of proper lens and camera technique, an object when increased a little over 50% in linear dimension would have the same definition as in the monochrome system.*

At the outset it should be pointed out that crispening has nothing in common with peaking, pre-emphasis or aperture-correction methods heretofore employed for high-frequency pictorial compensation, as will be shown in this paper.

The relation between bandwidth of a linear system and rise time for a suddenly applied voltage input step is well known. This has probably caused the casual investigator to dismiss the problem of improving rise time as insoluble. However, the well-known relations are confined to linear systems. Improvement of the rise time is possible by means of nonlinear operations performed on waveforms associated with a system of limited bandwidth. Such operations cannot be expected to yield a system output if the system input is a sinusoidal waveform of frequency higher than the limited bandwidth will pass. No new information can be produced at the output, but the original bandwidth-limited information can be changed in its nature.

In the case of television pictures, high-detail information is, for the most part, of the nature of isolated steps, and only rarely of a repeated nature approximating a steady-state waveform made up of frequency components above the system bandwidth limit. The "crispening" method described in this paper uses nonlinear circuitry to modify the nature of the isolated step response of bandwidth-limited systems. This gives television pictures the appearance of having been transmitted through a system of greater bandwidth than is actually used, except for omission of such high-frequency repetitive patterns, and inability to resolve closely spaced fine lines.

Basic Approach

The basic idea is to attempt to add to a waveform having a slow transition a second waveform which represents the difference between the waveform desired and the waveform originally present. Figure 1(a) shows an idealized waveform of slow transition, and Fig. 1(b) shows a family of curves depicting possible waveforms, any one of which can be added to it to make the resultant have an infinitely fast transition (see corresponding curve in Fig. 1(c)). As a less ambitious illustration, Fig. 2(b) shows a family of curves depicting possible waveforms which can be added to that of Fig. 2(a) to make the resultant have twice the original transition rate (Fig. 2(c)). Any of the three waveforms in Fig. 2(c) can be obtained from that of Fig. 2(a) by the use of the corresponding correction waveform in Fig. 2(b). It will be noticed that the correction waveform of Fig. 2(b) can be of a simple shape, for example, either a negative or positive triangular spike.

* The arithmetic mean between the number of alternate bright and dark lines in the horizontal and vertical directions for which total loss of definition occurs is a little over 50% greater for monochrome than for color. (The ratio of the frame frequencies is 2.4:1, so that a ratio of linear dimensions of $\sqrt{2.4}$ or 1.55:1 would give equal definition.)

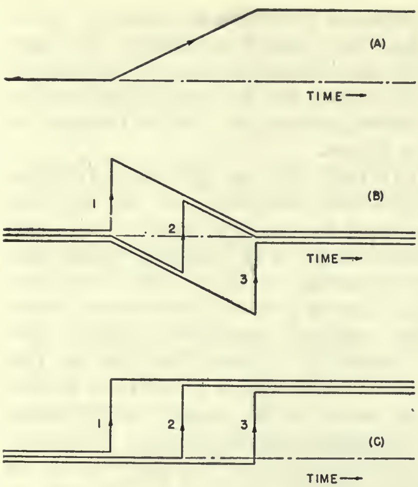


Fig. 1. (a) Waveform of slow transition rate; (b) added waveform for fast transition rate; (c) resultant waveform after addition.

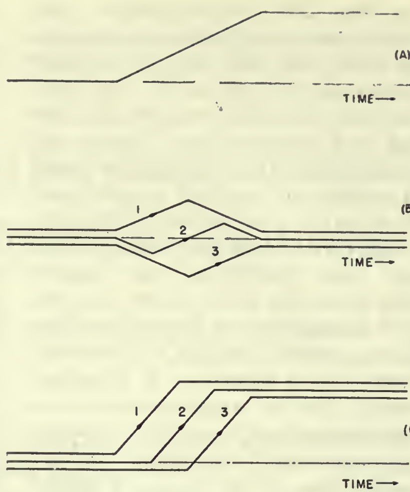


Fig. 2. (a) Waveform of slow transition rate; (b) added waveform for twice transition rate; (c) resultant waveform after addition.

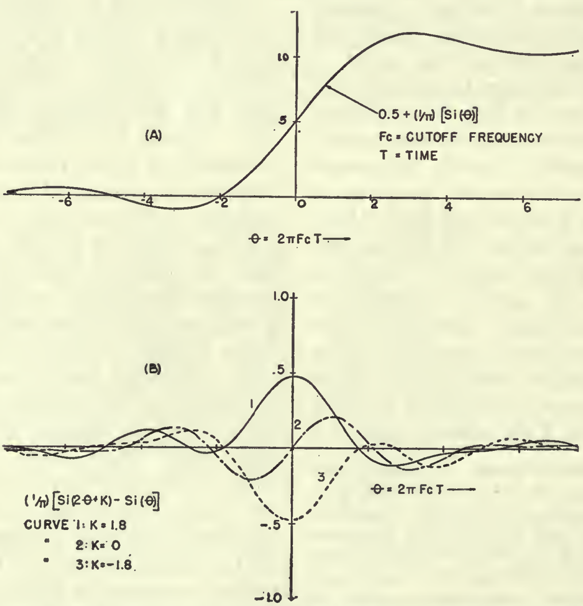


Fig. 3. (a) Transition waveform of ideal low-pass filter; (b) added waveform for twice transition rate.

In practice, the type of waveform to be corrected would be more like that of Fig. 3(a), the step response of an ideal low-pass filter. Any one of the curves of Fig. 3(b) represents the correcting waveform required to double the transition rate. Thus the resultant will duplicate the step response of a filter of twice the cutoff frequency. The correcting waveform could be approximated by a negative or positive triangular spike.

The negative or positive differential of the original waveform can serve as a useful approximation. Adding or subtracting the differential increases the transition rate, but may be accompanied by "overshoots," which sometimes are undesirable. This is to be expected since no nonlinear elements are involved. Looking at it from the corrective waveform standpoint, the added spike is wider than that most desirable.

If the differential of the original waveform is modified, making it less wide by using a nonlinear power law device (for example, squaring its amplitude for both polarities), a correcting waveform may be obtained, which gives a steepened resultant free from overshoot. But this holds rigorously for only one transition amplitude. If the differential of the original waveform is made less wide by clipping, passing only the peaks of the differential waveform, a correcting waveform may be obtained, which also gives a steepened resultant free from overshoot or undershoot. This result also holds true rigorously for only one transition amplitude, unless the clipping action can be made to follow any change in amplitude.

A shortened spike can be obtained from the differential if the latter is made available as the voltage from a low-impedance source feeding a rectifier having a load consisting of resistance and capacitance in parallel, and the current through the rectifier is used as the output spike. The spike amplitude is then nearly proportional to the transition amplitude. This method is employed in a practical "crispener" to be described.

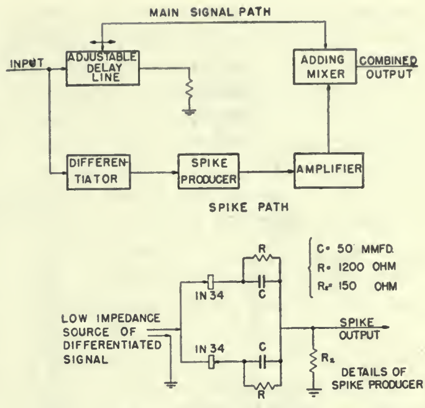


Fig. 4. Block diagram of simple crispening circuit.

In Appendix A the basic idea will be explored further to show that any degree of steepness correction in isolated transient steps is possible.

Applications

Figure 4 is a block diagram of a simple crispening circuit based on the above method. To insure that a spike can be centered halfway up the slope of the uncorrected waveform, an adjustable delay is included in the main signal path. The frequency response for circuits associated with the main signal path need only be good enough to accommodate all frequencies initially present in the input signal. The spike path after the spike has been formed, and the circuits handling the combined output, should preferably have at least twice the bandwidth of the input signal. Such an arrangement has been used for experimental observations and also has been tested in conjunction with color television receivers.

In the course of demonstrations of color television originating in New York studios and being shown in cities as far as Chicago, it was desired to apply a similar arrangement to the improvement

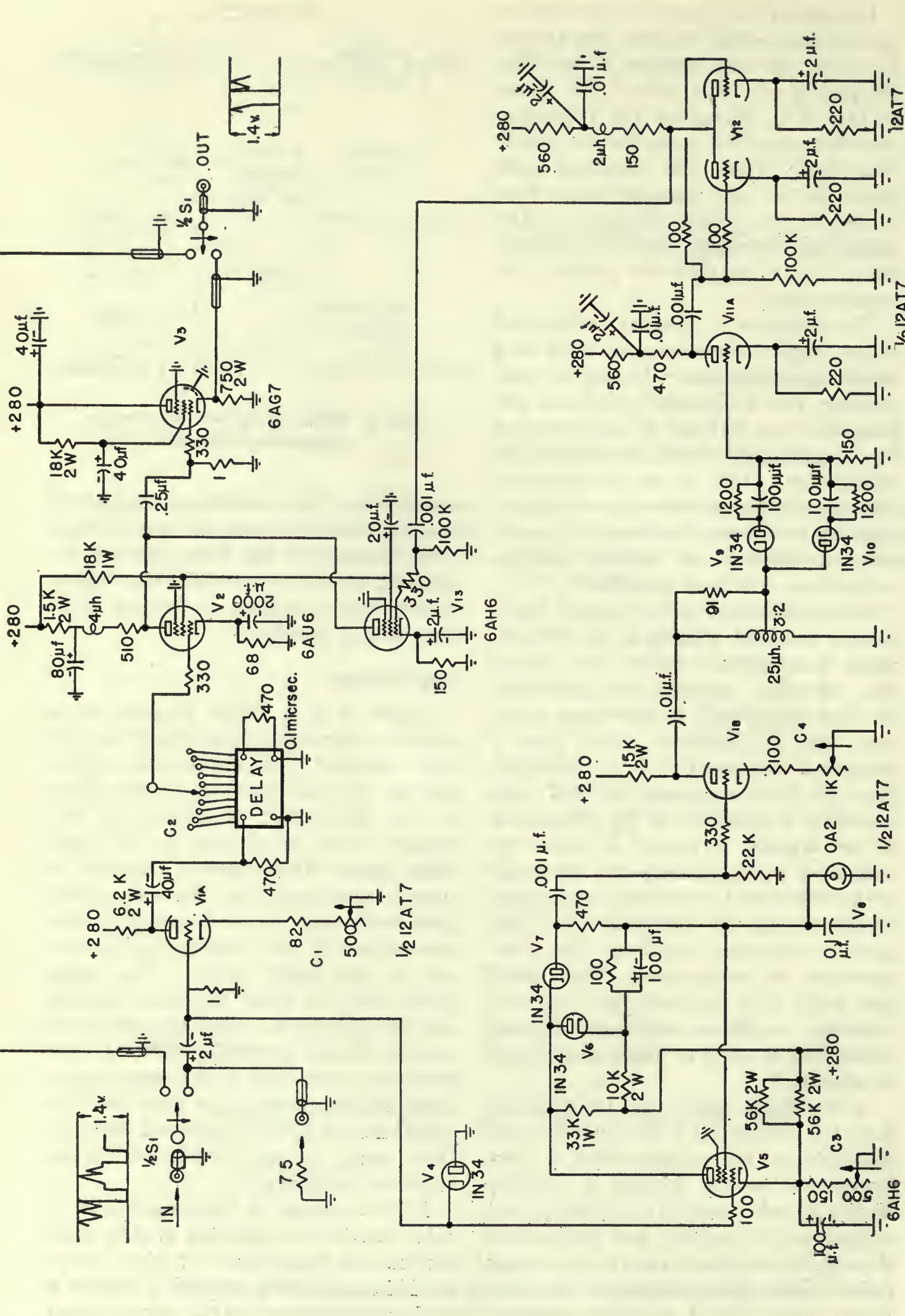


Fig. 5. Schematic of a practical crispening circuit.

of pictures transmitted by coaxial cable for which the cutoff frequency was about 2.7 mc. Several units were built for this purpose, of a sufficiently versatile nature to warrant giving a detailed description.

Figure 5 is the schematic diagram of this special crispener. It handles an input of 1.4 v peak-to-peak including synchronizing pulses, from a 75-ohm line. The output level and polarity into a 75-ohm line are the same as for the input. The circuits for the main signal path and combined output (V_1, V_2, V_3) are flat within 1 db to 6 mc, and 3 db down at 9 mc. The circuits associated with the spike path and combined output after spike production (V_{11a}, V_{12}, V_{13}, V_3) are flat within 1 db to 8 mc, and 3 db down at 10.5 mc. The main signal path includes a control, C_1, to adjust the overall gain to unity, and a control, C_2, to adjust delay in the main signal path, to allow shifting transitions so that the spike falls on the optimum part of the slope. If spikes are not injected, the overall output is essentially the same as the input except for delay.

Spikes for either direction of transition are produced by the crystal rectifiers V_9 and V_{10} with their associated *RC* loads. The input to the spike-producing rectifiers is essentially the differential of the input signal, obtained at low impedance by using a transformer which also serves as the differentiating inductive load for V_{1B}. The spike duration is mainly controlled by the *RC* values in series with V_9 and V_{10}, although also influenced by the frequency responses of circuits both preceding and following the spike formation. The spike path after spike formation includes the tubes V_{11A}, V_{12}, and V_{13}; the plate of the latter is in parallel with the plate of V_2 in the main signal path, at which point the spike is added on to the transition and the combined output fed to the output cathode follower V_3. No control is provided for spike duration. The *RC* values shown are used for "crispening" either coaxial cable television transmissions or transmissions received from a standard television transmitter by a representative television receiver, down 3 db at about 3.4 mc. The capacitors are reduced to 50 $\mu\mu$f when the unit is used to "crispen" pictures transmitted over a circuit that is down 3 db at 4 mc (telephone company microwave link). Control of spike amplitude is provided by a gain control, C_4, associated with the differentiator V_{1B}.

In some applications, these "crispeners" were used following stabilizing amplifiers, to which a television signal of low bandwidth and long rise time was applied. The stabilizing amplifiers reshaped the synchronizing pulses to have a much faster rise time, but left the slow rise time of the video signal unchanged. The crispening unit then required a clipper to cut out the synchronizing pulses before producing spikes; otherwise undesirably large spikes were caused by the synchronizing pulses. V_5, V_6, V_7 and V_8 constitute this clipper, the clipping level being adjusted by the control C_3. Naturally, this precaution is necessary only when the signals thus treated are intended for broadcast.

In future applications, a crispening circuit will be built into a suitable stabilizing amplifier, of the type that provides one path for video alone—to which crispening will be applied—and a separate path for reshaped synchronizing pulses alone. It is expected that this will require the addition of six miniature tube envelopes to the stabilizing amplifier, a net economy for applications requiring a stabilizing amplifier in conjunction with a crispening unit.

Results Obtained

In demonstrations of field sequential color television in cities remote from New York, some of which involved transmissions via standard telephone company coaxial-cable circuits, use of

Fig. 6. Picture transmitted with 4.5-mc cutoff frequency, uncrispened.

Fig. 7. Picture transmitted with 4.5-mc cutoff frequency; crispened.

Fig. 8. Picture transmitted with system flat to 10 mc, uncrispened.

"crispeners" gave a definitely more pleasing picture.

Figures 6, 7 and 8 show, respectively, field-sequential color television pictures of FCC approved standards transmitted with maximum bandwidth of 4.5 mc (3 db at 3.2 mc) uncrispened, the same crispened, and with a system flat to 10 mc uncrispened, as photographed from the screen of an industrial receiver. Figures 9, 10 and 11 show the reproduction of a test pattern under the same circumstances. Figure 12 shows the response frequency of the filter used to limit bandwidth to 4.5 mc. It can be seen that for the narrow bandwidth, even though the fine-detail part of the wedge is not reproduced, the part of the wedge that is reproduced is more clean-cut when crispening is employed; and in the photographs of picture material, the edges of objects are delineated in a manner that compares favorably with the 10-mc uncrispened picture.

Figure 13 is an oscilloscope picture showing superimposed the normal and crispened waveforms obtained from input steps of different amplitudes where the input steps have been passed through a low-pass filter of 2-mc bandwidth to the 3-db point.* The improvement due to crispening is clearly apparent, as well as the extent to which the "crispener" described achieves a correction independent of transition amplitude.

Figure 14, taken under the same conditions as those of Fig. 13, shows the normal and crispened waveforms obtained when a square input pulse of $\frac{1}{8}$-μsec duration is applied. This would give, theoretically, a peak of 48% of the asymptotic response to a long pulse. Doubling the bandwidth would raise

* The choice of a relatively low cutoff frequency (2 mc to the 3 db point) for the input signal makes the waveforms resulting from crispening less subject to modification by bandwidth limitations in the circuits that follow the crispening operation. This choice also represents an approximation to operations with coaxial-cable circuits.

the peak amplitude to 87%, an increase of 80%. Figure 14 shows that the amplitude does not increase appreciably, but that the pulse shape is improved, when crispening is applied. Isolated fine-line detail, therefore, is improved in quality by crispening but not brought up to the same intensity as with a true increase in bandwidth. Subjectively, however, the improved shape seems to give the impression of somewhat improved fine-line intensity also.

Home Receivers

An interesting application of crispening is in the improvement of color television picture appearance for home receivers. Considerable simplification is possible as compared to the system of Fig. 5. An experimental arrangement that has been used is shown in Fig. 15. Two double triodes and two crystal rectifiers are added to a conventional receiver. The connections to the added circuit are indicated by dotted lines.

The spikes are produced in a manner similar to that already described for the circuit of Fig. 5. After amplification, the spike is injected into the cathode of the picture tube while the main signal path leads to the grid in the usual manner. If more delay is needed in the main signal path as compared to the spike path, the inductance network that compensates the high-frequency response of the video output coupling arrangement can be modified, making it into a more extended low-pass filter circuit. The only control shown is for adjustment of spike amplitude.

This particular receiver required only a small voltage range to modulate the picture tube. If more swing were required, a power output stage might be required for the spike path. To avoid the need for a power stage, an alternative arrangement could utilize a similar chain of stages for crispening, receiving input from the grid of a low-level video stage, and feeding spike output to the output of the same stage. Relative delay adjustment could be made by modifying

Fig. 9. Test pattern transmitted with 4.5-mc cutoff frequency, uncrispened.

Fig. 10. Test pattern, transmitted with 4.5-mc cutoff frequency, crispened.

Fig. 11. Test pattern, transmitted with system flat to 10 mc, uncrispened.

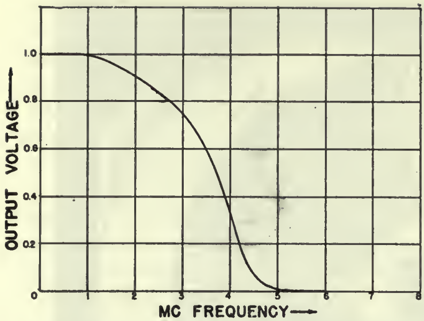


Fig. 12. Response frequency characteristic of a filter of 4.5-mc cutoff frequency.

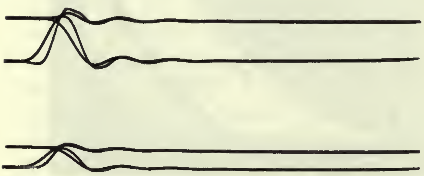


Fig. 13. Normal and crispened step waveforms for a system of 2-mc bandwidth to the 3-db point.

Fig. 14. Normal and crispened ⅛-μsec pulse waveforms for a system of 2-mc bandwidth to the 3-db point.

either the input or output coupling network for the low-level stage.

Other Applications

Other applications of the crispening principle may occur to the reader. One application of some interest is in the improvement of the appearance of recorded television transmissions. Crispening can be employed to obtain better overall sharpness at any point in the system following the film scanner, prior to the transmitter. For this application some control of spike duration would be desirable, in addition to control of spike amplitude.

Some Special Considerations

The effect of crispening circuits on the signal-to-noise ratio may be of importance if appreciable noise is present in the picture, either as a result of noise initially present before transmission or additional noise introduced at the receiver. The crispening circuit of Fig. 5 has been found to increase the level of random noise by roughly 50% which is comparable to the increase in noise that would have resulted from doubling the bandwidth. No exact analysis of the theoretical effect of crispening on signal-to-noise ratio has been carried out; the results would differ depending on the empirical circuitry employed to obtain a practical crispener.

The fact that any practical crispening arrangement devised represents an empirical design solution introduces a general difficulty in evaluating as a class the performance of crispening circuits for impressed waveforms of a complex nature. The elegant mathematical analyses such as are customary for circuits composed of linear elements cannot be used, since there is no unique solution to the circuit design problem. This is not to say that mathematics cannot be applied to any particular circuit; it can, although the nonlinear behavior introduces difficulty.

"Frequency response" is a meaningless term for nonlinear circuits, since for a given input frequency, the output consists not only of the original frequency, but also an infinite series of harmonics, the amplitudes and phases of which vary in different manners with change of the input frequency.

It might be thought that crispening circuits may increase the transition rate to that corresponding to a greater bandwidth than is actually used, not only for sharp brightness transitions in the picture material, corresponding to infinite bandwidth, but also for less sharp brightness transitions corresponding to the bandwidth actually used. A system behaving like an ideal low-pass filter with abrupt cutoff at 4 mc would give identical responses for an infinitely steep brightness transition or one having a waveform

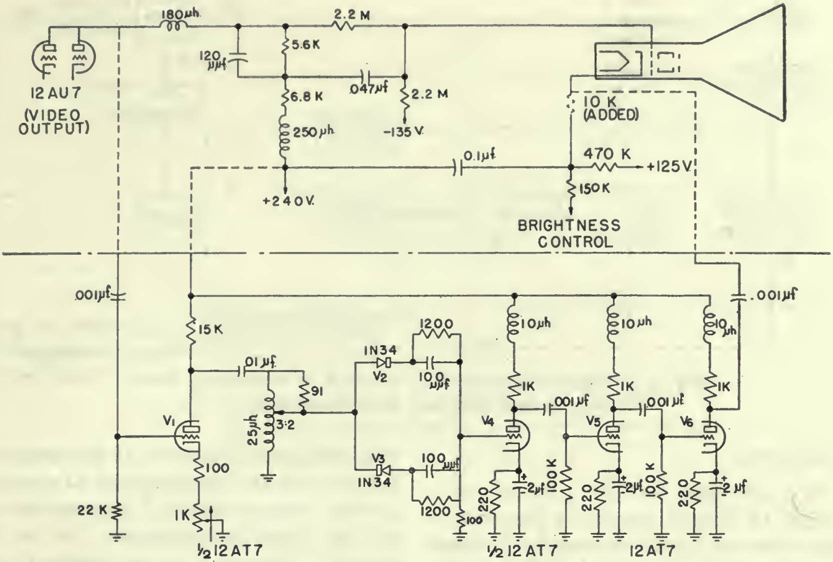


Fig. 15. Crispening circuit for a television receiver.

like the step response of an ideal filter of 4-mc cutoff. The latter response would be the same as that of an infinitely steep transition applied to two ideal low-pass filters in cascade.

Actually, when pictures are scanned, the transition waveforms are not of this shape. They are equivalent to the step response of a circuit having a gradual, rather than an abrupt frequency cutoff. If cascaded with an ideal low-pass filter of 4-mc cutoff, the overall frequency response falls off gradually up to the 4-mc limit; the amount of rounding that occurs before the abrupt drop at 4 mc depends on the steepness of the original transition. The steepness of the system response, therefore, also varies with the original steepness. When crispening is applied, as with the circuits of Figs. 4 and 5, which add a spike of amplitude and duration dependent upon the steepness of the applied transition, the overall response slope also varies with that of the original transition. It is true that the degree of sharpness may not be as faithfully reproduced as with an uncrispened system flat to 8 mc. This is due to a crispened 4-mc system having a tendency to introduce a little too much sharpness on transitions having an initial slope corresponding to that of the step response of a low-pass filter of 4- to 8-mc cutoff.

This imperfection is not appreciable in practice, since it occurs only on marginal degrees of sharpness in the picture being televised, and is outweighed by the advantage of better response sharpness on sharp transitions. Most objects appear either sharp or rounded; in cases where original sharpness is in the marginal region corresponding to step response of a low-pass filter of 4- to 8-mc cutoff, the degree of sharpness is usually of no significance to the observer in identifying the object or appreciating its nature. It is of importance that an initially sharp transition should look sharp. That the imperfection is not apparent is evidenced by the overwhelming preference of observers for pictures with crispening as against pictures without crispening.

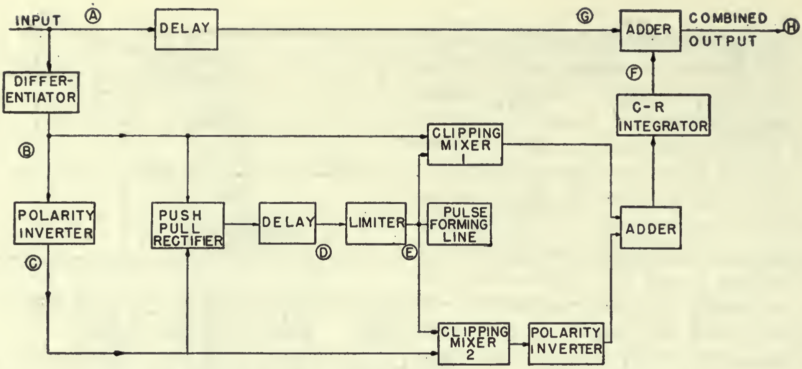


Fig. 16. Block diagram of a method of obtaining more than 2 to 1 increase in transition rate.

Conclusions

The rise time for the response of a system of limited frequency bandwidth when the excitation consists of isolated steps can be decreased beyond the theoretical limit for a linear system by utilizing nonlinear circuit elements following the point of bandwidth limitation.

"Crispening circuits" based on this principle can be designed and used to effect a significant improvement in the CBS color television pictures transmitted through a system with bandwidth limitations.

Such "crispening circuits" may have other useful applications.

Acknowledgments

Credit is due to members of the Columbia Broadcasting System engineering research department who have taken part in this development, in particular to J. J. Reeves who participated in the early experimental work and contributed many valuable suggestions.

Appendix A. More Elaborate Circuits

The relatively simple correction circuit of Fig. 4 is based upon the fact that the waveform to be added to the original to obtain a 2:1 increase in slope steepness is roughly of triangular shape and can be approximated by the output of simple circuits. Such circuits were so effective that little need appeared at the moment for pushing the development of circuits giving a higher order of approximation to the ideal performance. It is of interest, however, to see whether an increase of steepness substantially greater than 2:1 is possible.

One approach is to use for the correcting waveform, a nonsymmetrical triangle generated by integration of a short-duration pulse, modulating this pulse in accordance with the amplitude of the differential of the transition, and initiating the pulse by the passage of the differential waveform above a small fixed level. Both directions of transition must be accommodated, which introduces further complexity. The block diagram of Fig. 16 shows one method. The waveforms present at various points in this system are given in Fig. 17.

In all waveforms of Fig. 17, the solid lines represent an upward transition at the input, and the dotted lines a downward transition. The input signal is shown at A and its differential at B, or after polarity inversion at C. The push-pull rectifier, regardless of transition direction, produces a unidirectional output. This output, shaped like the magnitude of the differential, is used to produce a short pulse, timed to occur near the start of the input transition. For example, feeding the output into a

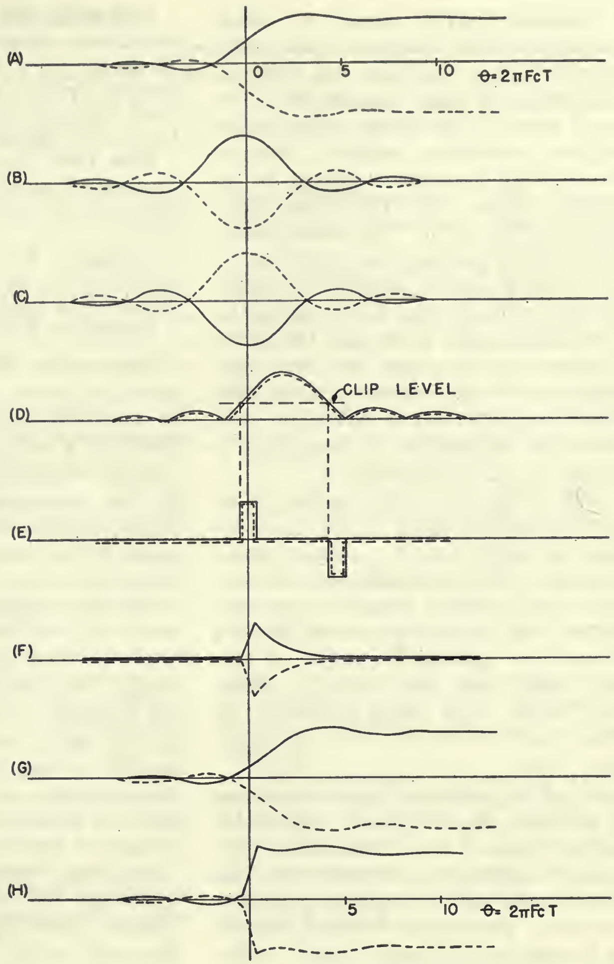


Fig. 17. Waveforms at designated points of Fig. 16.

limiter and short pulse-forming line, the waveform of E is produced. The positive pulse can be retained and the negative pulse that follows discarded by clipping in the "clipping mixers." The pulse amplitude and timing is almost independent of the transition amplitude if the level at the limiter is well above the clipping level. In order to center the positive pulse in the middle of the differential waveform, B, the input to the limiter is delayed as shown in D. The time delay shown is $(1/\pi F_c)$ where F_c is the cutoff frequency corresponding to the waveform A.

The clipping mixers modulate the pulse by the magnitude of the differential. Two are provided so as to handle both transition directions; one or the other yields an output. For an upward transition, the differential, B, modulates the pulse passing through clipping mixer 1. For a downward transition, the inverted differential C modulates the pulse passing through clipping mixer 2, which pulse is then inverted in polarity. In this way, a pulse is obtained at the adder which follows the transition amplitude and polarity, but is very short. The short pulse is then integrated by

a capacitor–resistor circuit, to obtain an asymmetrical triangular spike, characterized by a fast rise and slow fall dictated by the time constant *RC*. This spike, shown at F, is then added to the original waveform suitably delayed, shown at G, in order to obtain the resulting output H. The time delay shown is $(0.45/\pi F_c)$. The time constant, *RC*, is chosen so that the rate of fall of the spike F would nearly compensate for the rate of rise of the signal G. Thus the output H is only limited in shortness of rise time by the pulse duration of the pulse forming line. More complex means could be used instead of the simple *RC* integrator, to obtain better compensation.

While Fig. 16 would appear to be quite complex, many of the functions can be performed by simple circuit elements. For example, the differentiator and polarity inverter may be a tapped coil in the plate circuit of a triode; the push-pull rectifier, a pair of crystals; and the limiter, a 6BN6. For 3.4-mc input cutoff frequency the delay lines are only 0.094 and 0.042 μsec long.

It can be seen from this example that a decrease in rise time appreciably greater than 2:1 is obtainable. The example chosen to demonstrate this point is only one of a number of possible methods; presumably simpler schemes or arrangements of more nearly perfect performance could be devised.

Appendix B. Glossary of Terms

The glossary below gives the meaning of certain terms as used in this paper.

Crispening. Decreasing rise time for isolated step inputs by means of nonlinear circuits.

Crispness. In a picture, the degree to which edges of large objects approach discontinuous changes in brightness. For television waveforms this might be measured as the ratio of active horizontal trace time to the rise time for an isolated step input.

Definition. The number of alternate black and white lines that can be reproduced by a television system in a distance equal to the picture height. Used here as a single quantity combining vertical and horizontal definition.

Rise Time. The time required for the response to an isolated step input to rise from 10% to 90% of the ultimate amplitude.

Steepness. The maximum slope of a waveform of unit ultimate amplitude measured in inverse time.

Transition Rate. Inverse of rise time.

The above definitions are given to assist the reader and are not suggested as standard nomenclature. There is, however, a growing need for a nomenclature that can be used interchangeably in the photographic and electronic fields, in view of the increasingly close relation between the film and television industries.

The photographic concept of "sharpness" was not used in place of "crispness" as used here because, firstly, it would have required translation from the language of inverse distance to that of time ratio; and secondly, the photographic concept deals with the maximum first derivative of a curve, like "steepness" as defined above. The arbitrary nature of the curves obtainable with "crispening" makes the use of a concept involving rise time preferable to a concept involving the maximum first derivative, which could be large without having a satisfactory curve shape. Another photographic concept, "turbidity," involving the second derivative, was not used here for similar reasons. Attempts have been made* to evaluate the subjective impressions obtained from a curve of a given shape, but these were not utilized since a concept of "crispness" in terms of the generally accepted and readily described "rise time" seemed adequate for the purposes of this paper.

* A. V. Bedford and G. L. Fredendall, "Analysis, synthesis, and evaluation of the transient response of television apparatus," *Proc. IRE*, vol. 30, pp. 440–457; Oct. 1942.

Engineering Activities

Film Dimensions Committee The Committee met in May 1951 and in the absence of its Chairman, Dr. E. K. Carver, Dr. A. C. Robertson presided.

The main discussion centered around the problem raised by the decrease in the shrinkage characteristic of the film base over the years. In order to obtain optimum printing results now, negative film must have a pitch somewhat less than presently stipulated in the Standard for cine negative (PH22.34) under dimension B.

This then requires revision of the Standard. Two viewpoints were expressed as to how to proceed: (1) revise the Standard after sufficient data is available to standardize the cutting and perforating dimensions *at the time of use*, rather than at the time of manufacture; or (2) merely change dimensions B and L to a short pitch dimension in accord with present (but nonstandard) practices. It was indicated that the first procedure would require at least three years whereas the latter, possibly less than a year. Although it was generally felt that the first approach was more desirable, the other was considered a practical stopgap measure. It was, therefore, agreed to combine the two, preparing the groundwork for the long-range project while revising the present Standard for immediate use.

In addition, the problems involved in the use of film for computers were aired and several standards were reviewed as to their potential value for proposal as international standards.

Sound Subcommittee on Magnetic Recording The status of the three Proposed American Standards initiated by the group was discussed at the last Committee meeting, held during the 69th Convention in May 1951 and chaired by Glen Dimmick. At that time, the proposals were before the Standards Committee which was balloting on the question of preliminary publication for trial and comment. (They were published in the July *Journal*.) Comments which had been received in the course of the balloting were analyzed and most of the meeting was devoted to improving the three Proposals. In the end it was agreed that early publication was more important than minor, though valid, revisions which would require redrafting the Standards and additional Committee approval via letter ballots. The indicated changes could then be made after all comments resulting from trial publication have been received.

The remainder of the meeting revolved about the drafting of Magnetic Test Film Standards, primarily for azimuth and frequency of 16-mm and 35-mm film. Mr. Dimmick is to prepare preliminary drafts and circulate them to the Committee for comments.—H.K.

BOOK REVIEWS

Elements of Television Systems

By George E. Anner. Published (1951) by Prentice-Hall, 70 Fifth Ave., New York 11. i-xii + 760 pp. + 11 pp. appendix + 18 pp. problems + 13 pp. index. 400 illus. $5^1/_2 \times 8^1/_2$ in. Price $10.35.

Even with the postwar commercialization of television and the most generous oversupply of technical books, there has been no book that could satisfy the need for a genuine television engineering text. For the service technician there are so many books that they crowd the test equipment off his shelves; there is even a television encyclopedia on the service-technical level. But until the publication of Prof. Anner's volume, there has not been a thorough, rigorous engineering treatment of television.

For this reason alone, *Elements of Television Systems* is an important book. It is written by an eminently qualified person, for George Anner, as Assistant Professor of Electrical Engineering at New York University, has for three years held television courses at both graduate and

undergraduate levels and, during 1946–47, gave a special course in television for technicians at Columbia Broadcasting System. While at CBS he spent considerable time with operating personnel and equipment in studios and master control room, and at the transmitter.

The welcome novelty of Prof. Anner's approach is that he does not follow the custom of simply explaining the American system of television broadcasting. He treats television as a technical subject like any other, and begins at the correct place—the beginning—with the primary philosophy of translating a picture into an electrical signal, which is a single-valued function of time. Exploring the various methods of doing so, he explains why a certain system is the logical one, still in terms of methods and not of number of lines or frames.

The entire first section of the book deals with closed-circuit systems. This allows the distracting factors of standards details for a particular system and the irrelevant question of r-f transmission to be put aside so that the study is stripped to fundamentals. The figures governing critical flicker frequency for a cathode-ray tube, for example, are examined, so that the reader may use them as design criteria or use them to understand the reasons for broadcast standards, whichever his interest. The operation of the cathode-ray tubes is examined in detail and formulas for such items as electron velocity are derived. This basic approach is followed throughout the first section in the examination of scanning methods and generators, picture reproduction, camera tubes, and video amplification. Mathematical derivations, while not profuse, are present whenever warranted but not in such quantity as to preclude an informative qualitative reading of the text.

Part II deals specifically with the commercial telecasting system and its problems. Each of the adopted standards is described, in each case the factors governing the choice being recognized. Separate chapters are devoted to the existing and original special problems of standardization and the work of the committees, choice of the number of lines, synchronization, vestigial-sideband transmission, transmitters, receivers, stagger-tuned amplifiers, receiving antennas, and the particular methods and difficulties of transmitting motion picture films.

The final section is an analysis of color transmission with the same basic approach—response of the eye, color matching and other optical principles concerned with color. This is followed with details of the RCA, CBS and CTI systems. An appendix furnishes a detailed analysis, principally mathematical, of the interesting case of dot systems of color transmission.

There are 18 pages of problems for the student. Footnotes throughout the book indicate a wealth of literature, mostly periodical, for additional reference, and useful subject and author indexes end the book.

This is not a book for nonelectronics people to use in beginning a television education. It is definitely, however, highly recommended as a text for the electronics engineer to employ, for both educational and reference purposes, and in designing commercial and industrial systems and components.—*Richard H. Dorf*, Television Consultant, 255 West 84th St., New York 24.

Gobo, Cuffo and Cucalorus

Words, words, words! amusing, confusing and many of them unnecessary are packed into the *TV dictionary–handbook for sponsors* just published by Sponsor magazine, 510 Madison Ave., New York, at $2.00 per copy. This 70-page booklet lists 1000 television terms and although it is probably a handy guide for newcomers to the field of television production, it threatens to kick the props out from under the Society's motion picture and television glossary project.

Many television terms have been swiped from the movies, misinterpreted, then too loosely defined. *TV dictionary–handbook* does a good job of classifying and setting the record straight, but its chief merit is its breeziness.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal*.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1950 **Membership Directory.**

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Child, Harry R., Motion Picture Instructor, U. S. Army. **Mail:** 1025 E. 43 St., Austin, Tex. (A)

Einhaus, C. G., Manager, Photographic Division, Gardner-Denver Co. **Mail:** 1109½ Cherry, Quincy, Ill. (M)

Elias, Bernard L., Customer contact man, color print and film processing, Eastman Kodak Co. **Mail:** 724-A South Curson Ave., Los Angeles 36, Calif. (M)

Halliday, Kenneth N., Senior Mechanician, Test Division, Cape Town City Electricity Dept. **Mail:** 15 Wisbeach Court, Wisbeach Rd., Sea Point, Cape Town, South Africa. (A)

Heacock, R. H., Product Manager, Theatre Equipment, RCA Victor Div. **Mail:** Medford Lakes, N.J. (M)

Kortge, Kenneth M., Motion Picture Film Editor, Sound Engineer, J. R. Hunter—Capital Film Service. **Mail:** 233 S. Clemens St., Lansing 12, Mich. (A)

Lueders, Arthur L., Camera Designer, Bell & Howell Co. **Mail:** 6452 N. Bell Ave., Chicago 45, Ill. (A)

McBride, Russell R., Owner, Sound Recording and Engineering Firm. **Mail:** P.O. Box 596, Del Mar, Calif. (A)

Monson, Roger L., Projection Engineer, American Broadcasting Co. **Mail:** 2920 West Ave. 34, Los Angeles 65, Calif. (A)

Palmer, Solita, Composer, original music scores, Emerson Yorke Studio. **Mail:** 78 Engle St., Cresskill, N.J. (A)

Priebe, Roy E., Photographer and Teacher, Los Angeles Board of Education. **Mail:** 4209 W. 62 St., Los Angeles 43, Calif. (A)

Seelye, Vernon E., Equipment Repair, Capital Film Service. **Mail:** 1604 Illinois Ave., Lansing, Mich. (A)

Smith, Alan A., Process Control, Research, Warner Brothers. **Mail:** 503-B South Catalina St., Burbank, Calif. (A)

Tyler, Albert P., Supervisor of Motion Pictures, Humble Oil & Refining Co. **Mail:** 5223 Beech St., Bellaire, Tex. (M)

Weinberg, Sydney A., Associate in Radiology, Strong Memorial Hospital. **Mail:** 306 University Park, Rochester, N.Y. (M)

CHANGE OF GRADE

Byron, Donald S., Electrical Engineer, Cornell Aeronautical Laboratory. **Mail:** 507 Summit Ave., Jersey City, N.J. (S) to (A)

Hayes, Miles V., Lecturer, Harvard University. **Mail:** R.F.D., Maynard, Mass. (S) to (A)

Root, Lewis A., Sales Manager, J. A. Maurer, Inc. **Mail:** 22 South Court, Bayview Colony, Port Washington, N.Y. (A) to (M)

Back Issues of the Journal Available

The issues of May 1946, August 1946, February–July 1947 and September 1947 to date are available at $0.75 per copy from Robert G. Ellhamer, Box 2549, Hollywood Station, Los Angeles 28, Calif.

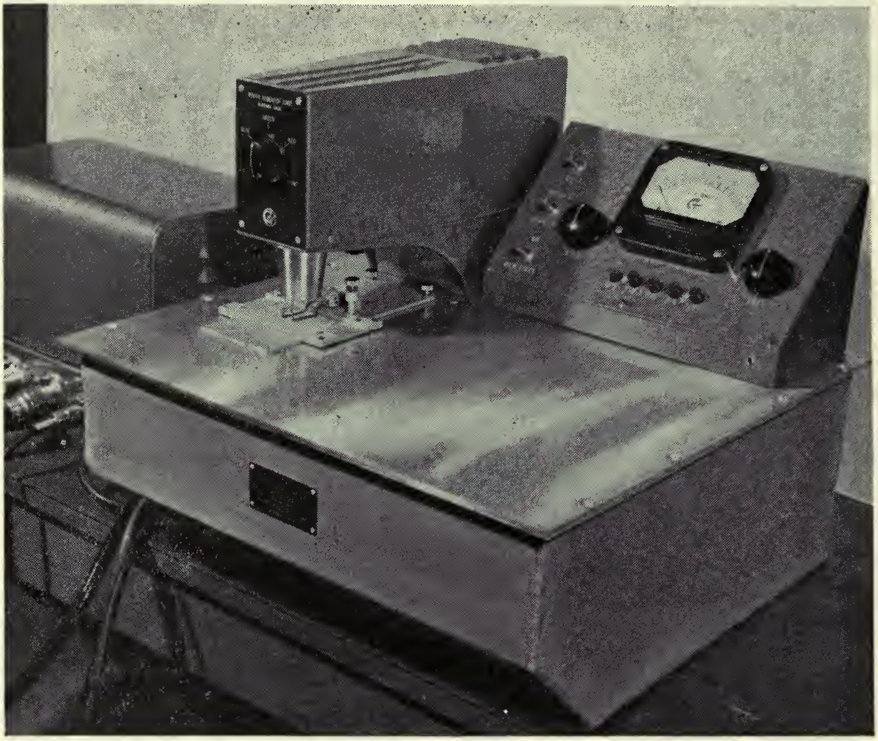
A set of Journals from October 1938 to the present date, except for the June 1939 issue, is available at $75.00 for the lot, from Harry Hollander, 21-36—77th St., Jackson Heights, L.I., N.Y.

American Standards form the technical foundation for motion pictures around the world. All current standards were listed by subject and by number in the *Journal* Index 1946–1950. Reprint copies of this list, which includes all previous *Journal* references to each standard, are available from Society Headquarters without charge.

Complete sets of all sixty current standards in a heavy three-post binder with the index are $13.50, plus 3% sales tax for purchases within New York City, and are available from Society Headquarters. Single copies of any particular standard must be ordered from the American Standards Association, 70 East 45th St., New York 17, N.Y.

New Products

Further information about these items can be obtained from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.



The Model III PRC Color Densitometer is a new instrument especially designed for color sensitometry by Photo Research Corp., 127 W. Alameda Ave., Burbank, Calif. In order to isolate the density component in each layer of multilayer film, the designers have considered that color filters having narrow band transmission must be used in the light beam increasing the effective sensitivity of the instrument by 100 to 1000 times. The instrument works as follows:

The light from the lamp passes through a chopper wheel, special heat- and infrared-absorbing filters, then through a filter wheel containing filters having narrow transmission bands—one each in the blue, green and red. This light beam is then focused to pass through the film sample. The light passing through the sample is picked up by a high-vacuum phototube and applied to a very stable high-gain a-c amplifier containing large amounts of negative feedback to produce high linearity and freedom from tube drift. The output of this amplifier is rectified and drives a meter having inverse-log response and therefore a scale having linear density divisions. A push-button range switch is incorporated so the full scale of the meter can be used for a density range of 0–1, 1–2, 2–3 or 3-4. This gives a useful scale length for 0–4 density of more than 12 in. The instrument also contains an electrical reference standard "density of 1" on a fifth push button making it self-calibrating.

An illuminated disk, added to this model, surrounds the phototube aperture enabling the operator to locate the area to be measured without added marking, thus adding to ease and speed of operation. An adjustable guide for 35-mm film is also furnished.

Dimensions of 16-Mm Film in Exchanges

By A. C. ROBERTSON

A survey has been made of the width, variation in width, and shrinkage of 16-mm film in a number of exchanges. These data are of use to designers of 16-mm equipment in describing the dimensions of film currently being used, and to purchasers of film in giving them some idea of the steadiness characteristics the film might possess.

THE PRESENT USE of 16-mm motion picture film as a professional medium requires that it give the best possible picture quality. The film must be manufactured carefully and handled equally carefully in each subsequent step in order to assure optimum performance. When this film is projected for large audiences, the magnification often is greater than that used for 35-mm film; therefore, for equal steadiness, the dimensional requirements are very severe. A new and exacting field of use is that of television broadcasting.

This paper is concerned with the dimensional characteristics of 16-mm film, particularly the width, variation in width, and to some extent, the shrinkage. Variations in width are often connected with comments about lateral unsteadiness of television images in programs using motion picture film for their subject matter. More often than not, this trouble is associated with 16-mm film made by slitting 32-mm film after processing. Since it was known in the beginning when Debrie introduced the use of 32-mm film, that the slitting after processing might be inaccurate, 32-mm film was made narrower than two strips of 16-mm films.[1] In fact, the first film was 1.252 in. in width and allowed about 0.005 in. for variation in slitting. This allowance was decreased to 0.001 in. later.

The exact magnitude of the slitting irregularities and their effects on the projected image have frequently been discussed, particularly in connection with the choice of the side of the film which is to be used in guiding in the picture aperture. Most of the discussions have been qualitative only, and the purpose of this report is to give as many definite measurements as possible in order to assist the formation of sound judgments in future discussions.

Presented on October 17, 1951, at the Society's Convention in Hollywood, by
A. C. Robertson, Manufacturing Experiments Div., Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y.

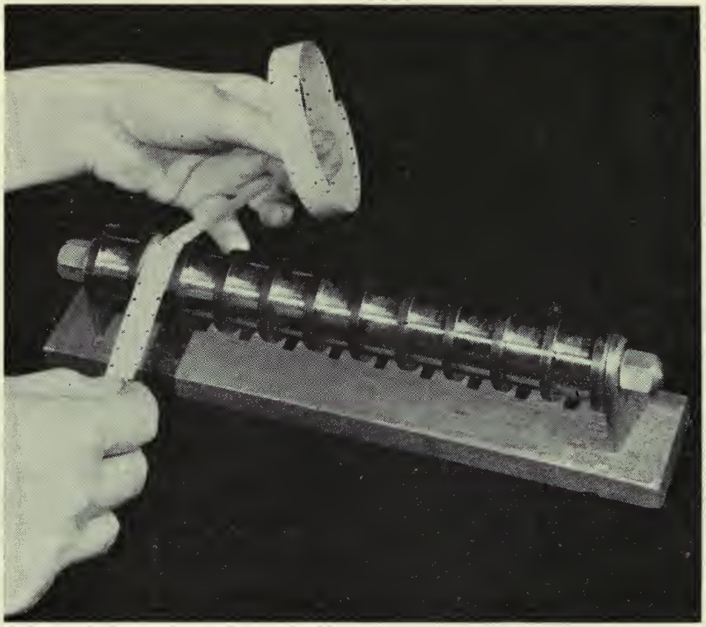


Fig. 1. Width gauge for use in the field.

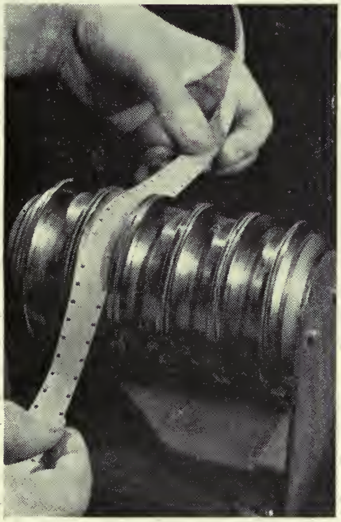


Fig. 2. Width gauge for use in factory.

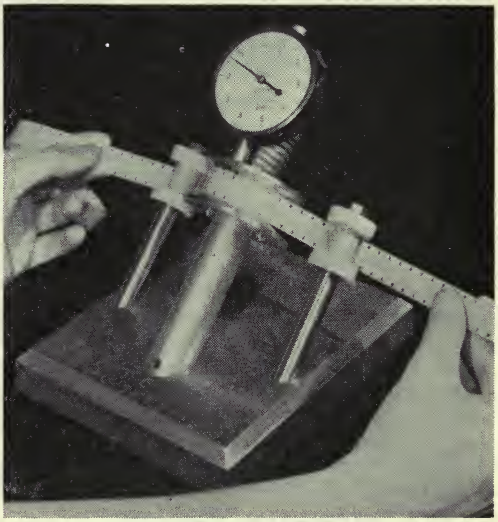


Fig. 3. Dial-indicator gauge for rapid measuring.

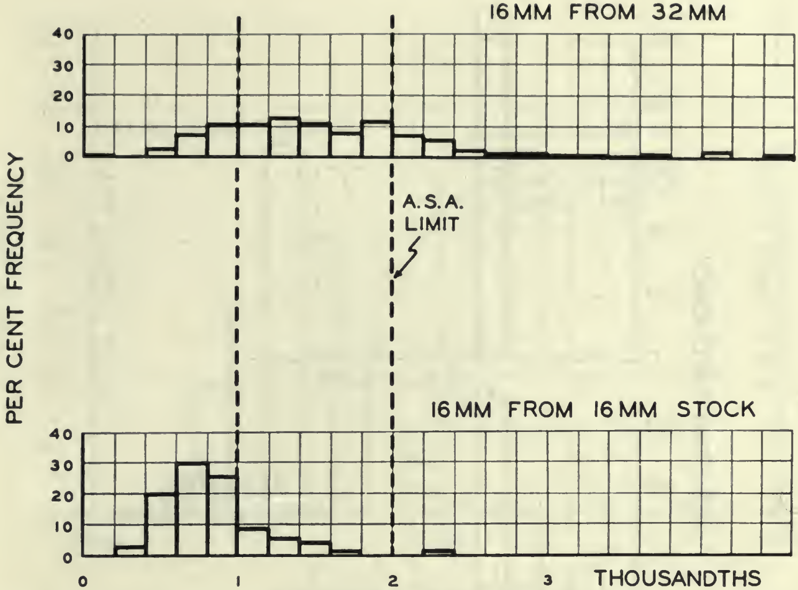


Fig. 4. Variations in width.

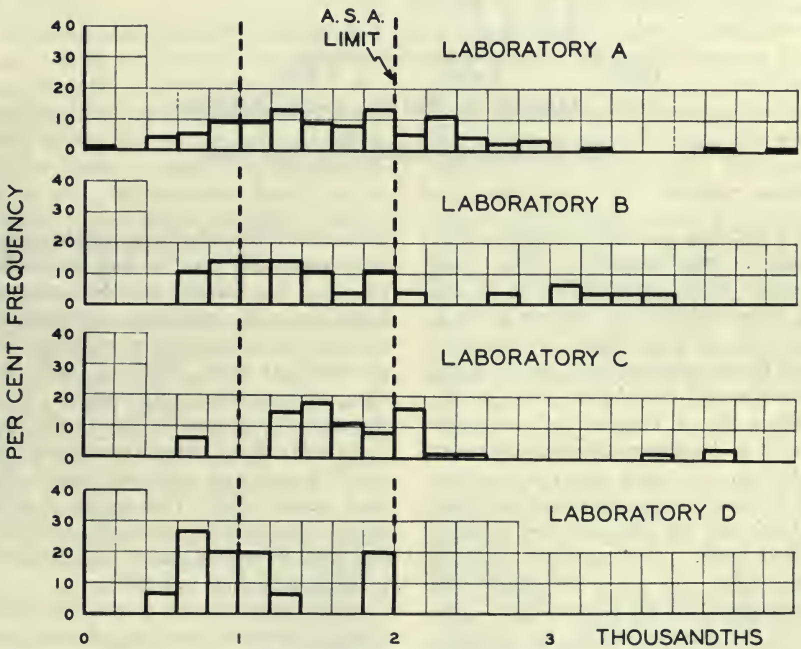


Fig. 5. Variations in width.

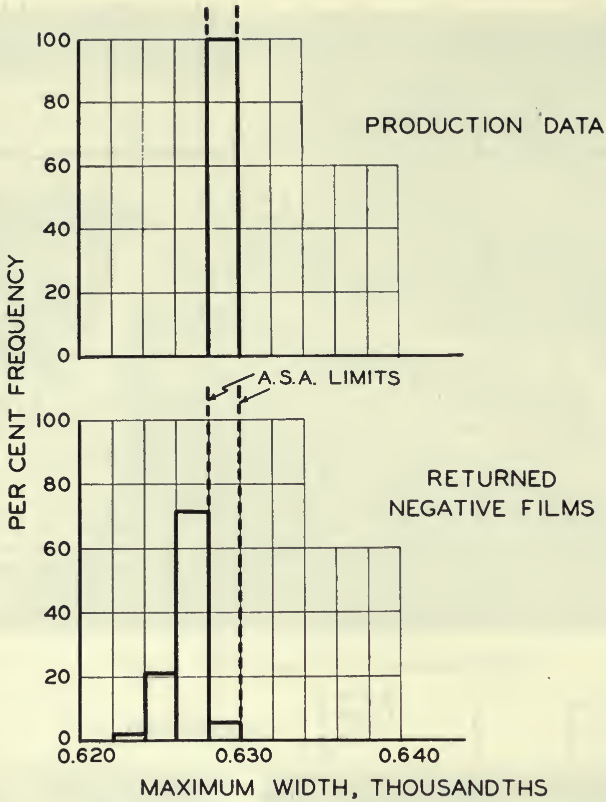


Fig. 6. Maximum width of 16-mm films.

It is not easy to obtain reliable, representative, measurements which truly represent trade conditions. It is well nigh impossible for one person to do it, and hence a joint effort is necessary. These measurements were taken, thanks to the cheerful permission given by distributors, in a number of exchanges thought to be representative of general conditions. In most cases, it was possible to learn which laboratory processed the film, and the data are also reported on that basis. The question might be asked—why did we not make the measurements at the laboratories? Naturally, the answer is that the sampling would give misleading results. The performance of the laboratory might appear to be unusually good or bad, depending on the conditions of the moment. Sampling at the exchanges automatically gave us an opportunity to examine films processed at many different dates, and thus prevents a bias in the results. There remains an unfavorable bias in the data, if one will call it a bias, to have some films which have been projected more often than other films. This situation seems normal and almost inevitable, since most old films have had more opportunity to be projected than new films.

Measurements were made in seven exchanges in recent months, and were combined with data obtained in seven other

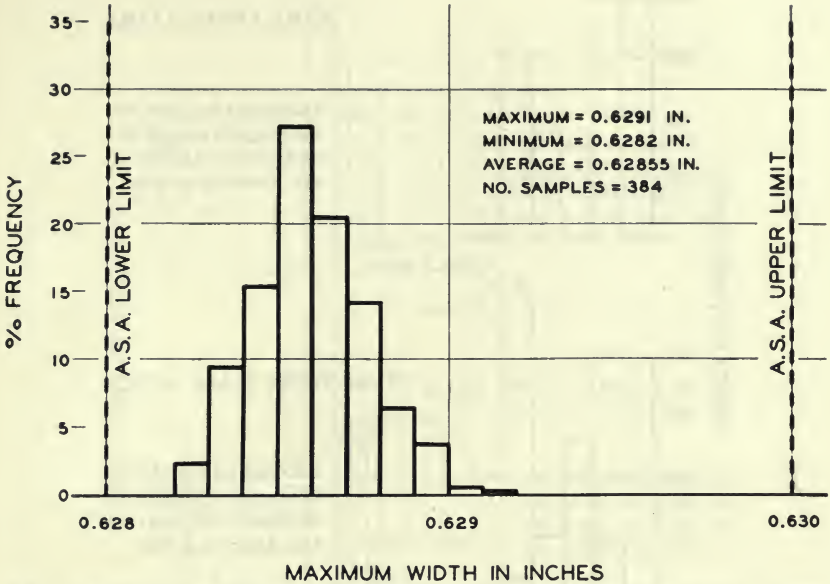


Fig. 7. Maximum width of 16-mm film, slit in Kodak Park, November, 1950.

exchanges during the period covering 1945–1950.

These data may be used for design purposes, which will include a choice of dimensions for projector sprockets.[2] Accordingly, the data on film shrinkages collected during the survey are included so one can have at hand data representative of the film currently found in exchanges. One easily available survey describes conditions in 1938.[3]

Methods of Measurement

Information bearing on troubles caused by wide film is obtainable directly by simple measurements. In Fig. 1 is shown a width gauge for use in the field. It is simply a series of "go" and "no-go" gauges, and is often called a "spool" gauge because of its resemblance to a number of spools on a stick. It can be used to measure film from 0.620 to 0.630 in. in steps of 0.001 in. A similar, larger, gauge for use in the factory is shown in Fig. 2. It measures by steps of 0.0005 in., which values can be further divided by the sense of touch. These gauges have solid hard surfaces and, therefore, are most reliable in determining actual width; however, they are not rapid in use. The dial-indicator gauge in Fig. 3 is more rapid in use, and is particularly useful in determining the periodic variation in width that we sometimes call "drunkenness." The gauge has moving parts and therefore must be maintained carefully if one is to be sure of the exact value of the maximum or minimum width. This requirement demands regular checking with a carefully made standard ring. Also, one must guard against wear, which forms grooves where the film bears on the measuring surfaces.

Variation in Width of Film

Now let us look at some of the results of the survey. It is generally felt that a variation in the width of the film in a regular, cyclic pattern, gives bad results on the screen. There is lateral motion which is soon recognized by the viewer, who soon begins to follow the motion to the disadvantage of the show.

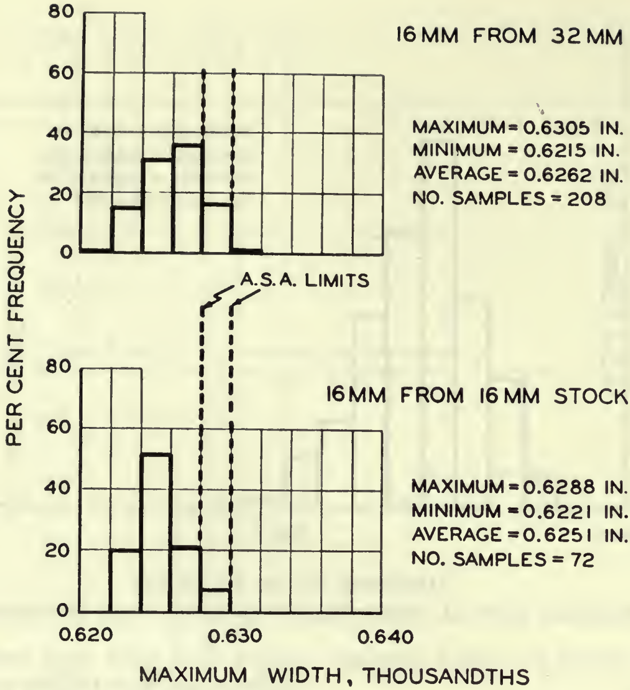


Fig. 8. Maximum widths.

The effect of cyclic variation in width of the film upon projection quality is not as easy to measure as the effect of some other defects. It was obviously impractical to rate the films examined in the exchanges for projection steadiness by jury, much less by our steadiness meter; therefore, we had to judge the quality of this film by the available mechanical measurements, although we know that under some circumstances apparently nonuniform film can give uniform, i.e., steady results, if conditions can be arranged so as to secure "cancellation" of errors.

The cancellation of errors by use of exactly identical design of corresponding parts in the equipment used for taking and projecting amateur films is well understood by a number of people but has not been widely discussed, probably because it has been taken for granted by the few people involved. The effect of cancellation is appreciable. Actually it is easier to show and to explain cancellation in the case of vertical unsteadiness than it is for the case of the lateral unsteadiness discussed thus far. In the case of vertical unsteadiness the conditions for cancellation are satisfied when the projector has the claw-to-aperture[4] distance the same as this relationship in the camera. This demonstration is easiest to make and to explain with films which are camera originals but it can also be done with prints. Robert P. Shea gave an interesting discussion of the complications introduced in making optical prints in his talk presented before the Society at the 1950 Lake Placid meeting.

In general, "cancellation" cannot be depended upon, considering the industry as a whole, because it depends upon making camera, printer, if any, and pro-

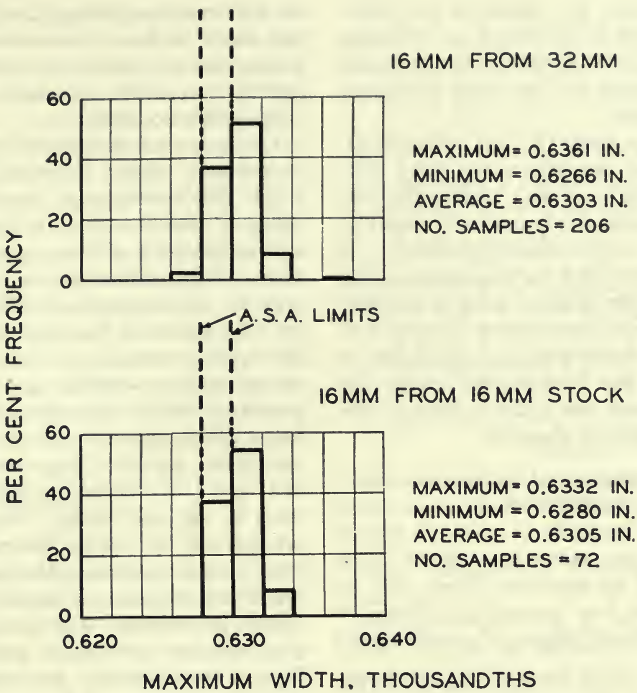


Fig. 9. Adjusted widths at 90% relative humidity.

jector essentially the same in detailed design. There are so many units (and so many conditions) present in the trade at the present time that conditions do not allow cancellation through identical design. Therefore we feel, in general, that nonuniform film will give unsteady images on the screen. In passing, it is worth noting that some people feel that it is improvident to drop all ideas of using cancellation in professional production and are suggesting the subject as a possible topic for standardization.

To return: Figure 4 shows the variation in width of 16-mm film including all the measurements which were made. The upper diagram shows the variation for 16-mm made from 32-mm film and the lower one the variation for film of our manufacture made as 16-mm. For best results the variation in width should be small, that is, the values should fall at the left of the diagram. For some time Kodak 32-mm positive film has carried a dot after the word "Safety" in the legend "Kodak Safety•Positive" in order to identify its kind.

The dotted vertical line on the right part of the graph is set at 0.0020 in. and represents the most liberal interpretation of the ASA specifications. We know this value is too great. Very few people seeing film which is as unsteady as this, for the second time, will agree that it possesses desirable qualities. The line on the left at 0.0010-in. variation seems to constitute a useful compromise as a tolerable limit for lateral movement, though values as low as 0.0008 in. have been recommended.[5,6] Twenty-one per cent of conventional film exceeds the 0.001-in. limit, as does 79% of the 16-mm film made from 32-mm film. Some of the variations in width seem to come from

handling, since the values for the variation in width of film found in exchanges are appreciably greater than we would have predicted on the basis of factory measurements.

Note that only $1\frac{1}{2}\%$ of conventional 16-mm film lies above the ASA line. However, 24% of the 32-mm film exceeds this value, and much of it would be expected to be excessively unsteady. A good portion of this variation presumably is controllable because there is a difference between laboratories, as shown in Fig. 5. Accordingly, it is reasonable to hope that the laboratories having the wider spreads can reduce them to the narrowest spread observed.

(*A demonstration reel was projected which showed the unsteadiness of the screen image produced by variations in width of different extents. It was pointed out that the 16-mm pictures were not made from 32-mm film, but were selected from an unofficial museum of defects kept for the purpose of eye calibration.*)

A certain need for improvement in the dimensions and consequently the behavior of some 16-mm film made by the 32-mm process is made clear by these measurements. The procedure by which improvement is to be obtained is not so clear. Proposals have been made to the Standards Committee of the Society for a standard describing 16-mm film made by the 32-mm process. The proposal was not entertained because most of the members of the Standards Committee felt that it did not matter how the film was made. Indeed the user need not, and may not, know how the film is produced; therefore, the film should meet the appropriate ASA specifications. In view of the fact that this specification is lenient, it actually devolves upon the purchaser to assure himself that the film is as good as he bargained for.

Maximum Width of Film

The maximum width of the film is a dimension of interest.[7] Film which is too wide may not perform well in projectors made to close tolerances, or in projectors operating under conditions where the film has swollen because of the prevailing high humidity.

Let us see what variation is encountered in raw film. Figure 6 shows in the upper graph the variation in the maximum width of the film as it is made. The narrow spread is due in part to the fact there is no difference in age. Lest someone feel skeptical about the graph, let it be said that the range in width of film seldom exceeds 0.0010 in., and that the variation in width for any one strip is generally much less than that. The lower graph shows how various lots of unexposed negative film, made between 1941 and 1950, varied in width. Variations in age and storage conditions increased the spread in dimensions. In Fig. 7 is shown the distribution of the slit width of film made during one month of factory production. The horizontal scale is spread out thirty times wider than in Fig. 6, thus showing that there is the Gaussian, theoretical distribution shape that one expects.

In Fig. 8 the upper chart shows the maximum width of 16-mm film made from 32-mm film. The lower chart shows the width of 16-mm film made from 16-mm factory-slit film. The amount of oversized 16-mm film made from 32-mm film is small, but real. This is a quantity which should be taken into consideration when designing equipment which is to operate with all available films and under all conditions, including those of high relative humidity.

Figure 9 shows what we think the width of the films of Fig. 7 would have been when freshly processed and conditioned to 90% relative humidity. The first correction was made by estimating what the width after processing would have been, from the shrinkage values observed in the exchanges. This value was then further increased by the appropriate amount to give the effect of conditioning to 90% relative humidity.

This high relative humidity would be encountered only in extreme cases, but these cases are believed to exist often enough so that they should receive consideration. Under these conditions the film is wide enough so that trouble can be expected if the effects of moisture[8] have not been taken into account.

Note that more than half of the films are oversized according to ASA specifications under conditions where 90% relative humidity prevails. It is not possible to guess what percentage of the films would cause jams, but it is possible to see that the spread of values for the 16-mm film made from 32-mm film is greater than for the 16-mm film made from 16-mm stock.

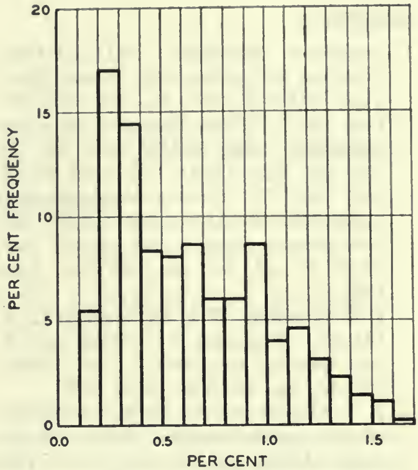


Fig. 10. Distribution of longitudinal shrinkage.

Shrinkage of Film

The longitudinal pitch of film found in exchanges, or its shrinkage, is generally a matter of more importance to the designer of projectors than to the current user or the original purchaser. The pitch is generally affected very little by the operations of the processing laboratory. It is true that some processing equipment, which uses high tensions, can stretch the film put through it by about 0.05%. This value is negligible compared to the changes in length that come with time.

Figure 10 shows the distribution of longitudinal shrinkage for all films measured in the exchanges. Note that there is no film with a shrinkage over 1.7%. To design sprockets for film of greater shrinkage than this will generally give sprocket teeth that are quite thin if there are many teeth in contact with the film. If a design value as small as 1.5% is adopted, then there is a chance of about one in sixty that the perforations in some film will interfere with the sprockets and be damaged. Actually, the choice of longitudinal dimensions is also affected somewhat by the local deformation around the edge of the perforation. This deformation is caused by tension put on the film by the sprockets, a matter discussed by Vilbrandt[9] several years ago.

By referring to Fig. 8, we ought to be able to obtain the narrowest (maximum) width of film measured in the survey. Actually 0.6215 in. was the lower range of the gauge, and so we could not read smaller values. There were $1\frac{1}{2}$% of film in the class 0.620 in. to 0.622 in. Accordingly, the uncertainty is not a great one, and indeed not a vital one. In general, if a 16-mm projector is designed for wider film than that used, little harm will be done to the film. There will be no tearing of perforations as is the case when the longitudinal pitch is below the design value, though sound-track placement will be affected. Sound-track placement was not measured in this survey. It may be expected that the errors of placement would be about the same as those of centering the film in slitting and would show a fluctuation about as great as the variation in width.

Thanks are due to those in the industry who made possible this survey and particularly to Daniel Botkin and Eldon Moyer of our division for their care in taking many measurements and reducing the data to useful form.

References

1. American Standard, PH22.71-1950, "Cutting and perforating 32-mm film," *Jour. SMPTE*, vol. 56, pp. 235–240, Feb. 1951; "Three Proposed American Standards, *Jour. SMPE*, vol. 52, pp. 223–230, Feb. 1949; American Standard, PH22.73, "Cutting and perforating dimensions for 32-mm on 35-mm motion picture negative raw stock," *Jour. SMPTE*, vol. 56, pp. 685–686, June 1951.
2. J. S. Chandler, D. F. Lyman and L. R. Martin, "Proposals for 16-mm and 8-mm sprocket standards," *Jour. SMPE*, vol. 48, pp. 483–520, June 1947.
3. J. A. Maurer and W. Bach, "Shrinkage of acetate-base motion picture films," *Jour. SMPE*, vol. 31, pp. 15–27, July 1938.
4. American Standard, Z22.8-1950, "Location and size of picture aperture of 16-mm motion picture projectors," *Jour. SMPTE*, vol. 54, pp. 498–500, Apr. 1950.
5. R. E. Stephens, "Optical and mechanical characteristics of 16-mm motion picture projectors," Circular of the National Bureau of Standards, C437, p. 17, June 1942.
6. American Standard, Z52.1-1944, "Specifications for service model 16-mm sound motion picture projection equipment," American Standards Assn., 70 E. 45 St., New York City, April 1944.
7. J. J. McCormick, "U.S. Navy projection specifications," *Intl. Projectionist*, vol. 25, no. 6, p. 26, June 1950.
8. *Eastman Motion Picture Films for Professional Use*, Eastman Kodak Company Publication, Rochester, N.Y., 1951, p.12.
9. C. F. Vilbrandt, "The projection life of 16-mm film," *Jour. SMPE*, vol. 48, pp. 521–542, June 1947.

Use of Glacial Acetic Acid in the Determination of Metol in Developer Solutions

By WILLIAM R. CROWELL, HARVEY E. GAUSMAN, Jr., and HARLAN L. BAUMBACH

Although metol behaves as a very weak base in aqueous solutions, it acts as a strong base in glacial acetic acid and can be titrated with glacial acetic acid solutions of perchloric and sulfuric acids, using an indicator. The end point is much sharper with perchloric acid than with sulfuric acid as shown by potentiometric titration curves of the two acids. Procedures and results are described for the analysis of several types of developer solutions employing glacial acetic acid solutions for the metol determination and ceric sulfate for the determination of hydroquinone.

Conant and Hall,[1] Hall and Werner,[2] Nadeau and Branchen[3] and recently Markunas and Riddick[4] have shown how bases very weak in aqueous solutions can be titrated as strong bases in glacial acetic acid solutions. In a recent note Idelson[5] has suggested that glacial acetic acid can be used as a medium for the determination of metol in developer solutions. It is the purpose of this paper: to show how this method can be applied to the determination of metol in developer solutions using an indicator without the necessity of a potentiometric titration; to compare titrations made with perchloric acid with those made with sulfuric acid; and to show how hydroquinone may be determined by titration with ceric sulfate of the solution in which the metol had previously been determined.

A contribution submitted August 27, 1951, by William R. Crowell, Dept. of Chemistry, University of California at Los Angeles, Los Angeles, Calif., and Harvey E. Gausman, Jr., and Harlan L. Baumbach, Paramount Pictures, Inc., Hollywood, Calif.

Preparation and Standardization of Acid Solutions

First, prepare a standard sodium acetate solution by weighing out sufficient dry sodium carbonate to make an approximately 0.0500 N solution in the volume desired. Add this solid to a somewhat less volume of 99.5% glacial acetic acid, dissolve, and make up to volume. Prepare an approximately 0.0500 N solution of perchloric acid from the 70–72% reagent by weighing out the proper amount and making it up to volume by the addition of glacial acetic acid. In the same manner a 0.0500 N solution of sulfuric acid may be prepared from the concentrated acid.

All these reagents should be stored in glass containers provided with airtight

glass stoppers. The titrations can be performed with 5-ml microburets with glass-stoppered reservoirs, side arms and two-way stopcocks. During titrations calcium chloride drying tubes should be attached to the reservoir opening and to the top of the buret tube. When the burets are not in use the reservoir drying tube may be replaced by the glass stopper and the connections of the drying tube attached to the buret tube may be closed off by suitable pinch clamps.

To standardize the acid, deliver into a 125-ml Erlenmeyer flask 50 ml of glacial acetic acid, 30 ml of ethyl acetate, 2–4 ml of the standard sodium acetate solution, and three drops of crystal violet indicator consisting of a 0.2% solution in glacial acetic acid. Titrate with the acid to the point at which the reddish violet of the base changes to a blue or greenish blue. The perchloric acid end point is quite sharp and only a fairly good light is necessary, but sulfuric acid requires good illumination such as that furnished by a Fisher Illuminator, and a comparison solution will probably be necessary, at least until one becomes accustomed to the end-point change. The comparison solution may be that resulting from a previous preliminary titration, or a $KHSO_4$ solution in the glacial acetic acid–ethyl acetate indicator mixture. For each acid a blank correction should be made in the volume of acid required. This may be determined by adding the acid to a mixture containing the same amounts of glacial acetic acid, ethyl acetate and indicator until the color matches that of the comparison solution.

For practical purposes in the analysis of developer solutions it is not necessary that the glacial acetic acid solutions be strictly anhydrous. The small amounts of water in the glacial acetic acid itself, as well as that liberated in dissolving the sodium carbonate and that contained in the concentrated perchloric and sulfuric acids, is not sufficient to affect seriously the sharpness of the end points.

Orange IV (tropaeolin 00) was also found to be a very satisfactory indicator, the color change being from yellow or orange-yellow to pink.

In the standardization of sulfuric acid solutions it should be remembered that the equivalent weight of the acid is equal to its molecular weight. Evidently only the first stage of ionization of the acid is sufficient to give a satisfactory end-point change and there appears to be no appreciable interference by the second stage.

Determination of Metol

Into a 50-ml separatory funnel pipet 10.0 ml of the developer solution, add two drops of thymol blue indicator and 6 *N* sulfuric acid dropwise until the solution just turns yellow (pH 8.0 to 8.5). Introduce 4–5 grams of potassium bromide and shake until it is dissolved. Add to the funnel 15 ml of ethyl acetate and shake for about three minutes, taking care that there is no loss through the glass stopper of the funnel due to the thermal expansion of the ethyl acetate. Allow the funnel to stand about three minutes or until the layers have separated completely and drain the aqueous layer into a 50-ml beaker, taking care that all the aqueous phase passes out of the stopcock bore. Pour the ethyl acetate layer into a dry 100-ml beaker, and from this to a second and to a third beaker, and finally into a 125-ml Erlenmeyer flask containing 50 ml of glacial acetic acid. Allow any liquid remaining in the stopcock bore of the separatory funnel to drain into the beaker, return the aqueous portion to the funnel, and rinse the beaker with 15 ml more of ethyl acetate, adding this to the funnel. Make a second extraction in the same manner as that made for the first portion, again adding the second extract to the glacial acetic acid.

To the glacial acetic acid mixture add three drops of crystal violet or orange IV indicator solution and titrate with standard acid, following the same procedure as that used in the standardization. The

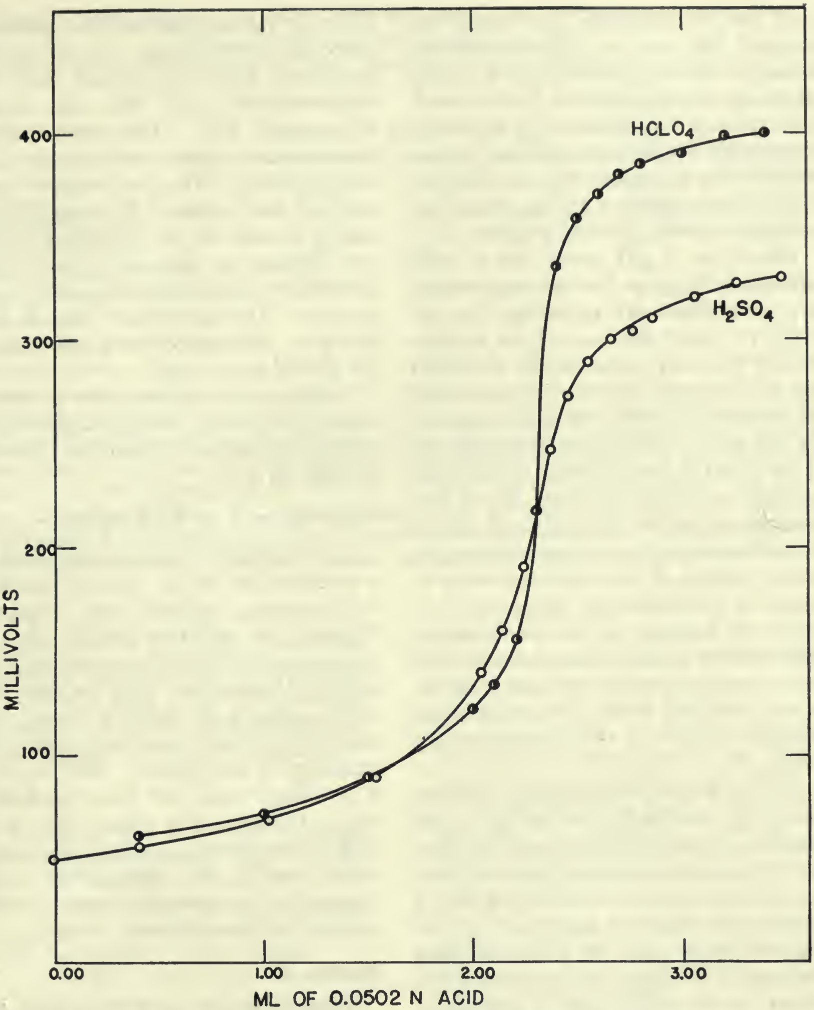


Fig. 1. Titration of metol base in glacial acetic acid.

same comparison solution may be used. The blank correction can be obtained by following the foregoing procedure on a solution with the same composition as the developer except that the metol is omitted.

Potentiometric Titration of Metol Base With Perchloric and Sulfuric Acids

In order to study the end points obtained in the titration of metol base with perchloric and sulfuric acids, potentiometric titrations were carried out on the glacial acetic acid–ethyl acetate mixtures. A Beckman Type G or Type H pH meter employing glass and calomel electrodes can be used to measure the voltages. If a Beckman saturated calomel electrode is used for a large number of runs, it should not dip directly into the glacial acetic acid mixture as it might eventually cease to function. This diffi-

culty can be overcome by having the electrode dip into an aqueous saturated potassium chloride solution which in turn makes connection with the glacial acetic acid mixture by means of a saturated potassium chloride agar bridge. More reproducible potentials may be obtained if the bridge contains a glacial acetic acid saturated lithium chloride solution.

The Type G pH meter has a scale sufficiently large so that no supplementary connections are necessary, but the Type H meter because of its smaller voltage capacity requires the introduction of a counter potential in series with the calomel electrode and its terminal on the pH meter. This counter voltage can be furnished by connecting a 50,000-ohm variable resistance rheostat across the terminals of a $1\frac{1}{2}$-v dry cell and taking off sufficient counter voltage to bring the initial reading of the pH meter scale to about 50 mv (millivolts) when the electrodes are dipping into the glacial acetic acid mixture before the start of the titration. In this case it is obvious that the voltage readings have no particular significance as far as the pH values are concerned.

Figure 1 shows potentiometric titration curves for perchloric and sulfuric acid titrations of glacial acetic acid solutions of ethyl acetate extracts obtained from an aqueous solution containing 2.00 g/l (grams per liter) of metol, 45 g/l of sodium sulfite and 40 g/l of sodium carbonate. Voltage readings were obtained by use of the Type H pH meter. It will be observed that while the perchloric acid inflection is much sharper than that of the sulfuric acid, the latter is quite sharp and the end point should be capable of recognition with an indicator without serious difficulty. Over an interval of 0.2-ml the perchloric acid inflection is about 900 mv/ml, while the sulfuric acid inflection is about 400 mv/ml.

In another series of runs the inflections with perchloric, sulfuric, toluenesulfonic and hydrochloric acids were compared. Over a 0.2-ml interval the millivolts inflection per milliliter were as follows: perchloric acid 950, sulfuric acid 340, toluenesulfonic acid 350, and hydrochloric acid 330. The toluenesulfonic acid solution was prepared from the dried monohydrate. The hydrochloric acid solution was prepared by taking the required volume of the concentrated acid and adding an amount of acetic acid anhydride equivalent to that of the water present. The latter may also be prepared by adding the dry gas directly to the glacial acetic acid.

Isopropyl acetate may also be used to extract the metol. Methyl acetate is not satisfactory because of the high solubility of water in it.

Determination of Hydroquinone

The hydroquinone is determined by a modification of the method described by Brunner, Means and Zappert.[6] Transfer the solution remaining after titration of the metol base with acid into a 250-ml beaker and wash the flask with three portions of distilled water until about 55 ml have been used, adding the washings to the beaker. Add 10 ml of 6 *N* sulfuric acid, two drops of 0.02 *M* ferroin indicator and titrate with 0.1 *N* ceric sulfate solution, using a mechanical stirrer, until the pink-orange color changes to a greenish yellow which persists for about 30 sec.

Results

Table I shows results of analyses carried out on several types of developer solutions, most of which were supplied by the Paramount Pictures laboratory.

The same procedure was applied to an Ansco Color Second Developer for the determination of the diethyl-*p*-phenylenediamine chloride in a solution containing 4.5 g/l of this constituent, 1.0 g/l of sodium bisulfite, 70.0 g/l of sodium carbonate and 2.50 g/l of potassium bromide. Results of the glacial acetic acid titration were 4.42 ± 0.03 g/l and of the ceric sulfate titration 4.52 ±

Table I. Determination of Metol and Hydroquinone in Developer Solutions
(All concentrations are in grams per liter)

	1 Positive Developer	2 Positive Developer	3 Negative Developer	4 Negative Sound Track	5 Ansco First Developer
Metol conc.	2.00	2.06	1.00	0.33	3.50
Hydroquinone conc.	3.50	3.62	0.50	1.80	6.50
Sodium sulfite conc.	45.0	45.0	50.0	50.0	50.0
Sodium carbonate conc.	40.0	40.0	—	—	40.0
Potassium bromide conc.	—	4.0	0.30	0.16	2.0
Borax conc.	—	—	10.0	10.0	—
Potassium thiocyanate conc.	—	—	—	—	2.0
% error in metol	±0.5	0.0	0.0	+3.0	±0.3
% error in hydroquinone	−1.0	+0.3	−2.0	−0.7	−1.4

Developers 1 and 5 are unused developers and percentage errors are based on the amounts of metol and hydroquinone in the samples weighed out. The purity of the metol and hydroquinone was determined by titration of their sulfuric acid solutions with ceric sulfate. Numbers 2, 3 and 4 are used developers and the percentage errors are based on the deviations from the results obtained by the method of Baumbach.[7] The low results usually obtained in the case of hydroquinone are probably largely due to air oxidation.

0.03 g/l. In other words the ceric sulfate results were 2.2% higher than those obtained in the glacial acetic acid titration. In the case of such developers there appears to be no particular advantage in employing the latter method.

References

1. J. B. Conant and N. F. Hall, "A study of superacid solutions: II," *J. Am. Chem. Soc.*, vol. 49, p. 3062; 1927.
2. N. F. Hall and T. H. Werner, "A study of superacid solutions: III," *J. Am. Chem. Soc.*, vol. 50, p. 2367; 1928.
3. G. F. Nadeau and L. E. Branchen, "The quantitative titration of amino acids in glacial acetic acid solutions," *J. Am. Chem. Soc.*, vol. 57, p. 1363; 1935.
4. P. C. Markunas and J. A. Riddick, "Titrimetry in glacial acetic acid," *Anal. Chem.*, vol. 23, p. 337; 1951.
5. M. Idelson, "Note on metol analysis in photographic developers," *Jour. SMPTE*, vol. 54, pp. 492–493, Apr. 1950.
6. A. H. Brunner, Jr., P. B. Means, Jr., and R. H. Zappert, "Analysis of developers and bleach for Ansco Color Film," *Jour. SMPE*, vol. 53, pp. 25–35, July 1949.
7. H. L. Baumbach, "An improved method for the determination of metol and hydroquinone in photographic developers," *Jour. SMPE*, vol. 47, pp. 403–408, Nov. 1946.

Observer Reaction to Video Crosstalk

By A. D. FOWLER

Presented here are results of tests to determine how much video crosstalk can be tolerated in black-and-white television pictures. Experienced observers viewed a television picture and rated the disturbing effects of controlled amounts of crosstalk from another video system. Crosstalk coupling was simulated by a network which permitted changes in frequency characteristic as well as in coupling loss. Tolerable limits for crosstalk coupling are derived from the test results.

VIDEO CROSSTALK becomes an important consideration when two or more video transmission systems operate on adjacent facilities. If the coupling between systems is excessive, crosstalk from one system will seriously impair the picture transmitted by another. To eliminate crosstalk coupling entirely is usually impracticable, if not impossible; to reduce it by even modest amounts is sometimes difficult and expensive. The question naturally arises as to how much crosstalk can be safely tolerated. To answer this question, a series of tests, similar to those described in a previous paper,[1] was made at Bell Telephone Laboratories. Observers were asked to rate the disturbing effects of various amounts and kinds of crosstalk in a standard black-and-white television picture. The purpose of this paper is to describe those tests and to present the values of crosstalk limits derived from the experimental data.

In all tests artificial crosstalk coupling was used. The disturbing television signal was fed into the disturbed television system through an attenuator and a network: the former controlling the flat coupling loss, and the latter imparting a desired loss-frequency characteristic. This type of coupling is called "lumped" to distinguish it from coupling distributed along transmission lines. The latter comprises components which may have different propagation times. Requirements for lumped coupling are probably somewhat more severe than for distributed coupling.

Four different loss-frequency characteristics were employed. They ranged from flat, which gives an undistorted crosstalk image, to very steeply sloping (less loss at higher frequencies). This range covers most of the general shapes of characteristics found in practice.

Presented on October 15, 1951, at the Society's Convention at Hollywood, Calif., by A. D. Fowler, Bell Telephone Laboratories, Inc., Murray Hill, N.J.

If strong enough, video crosstalk appears as an image of the unwanted signal moving erratically back and forth across the wanted picture. This motion occurs, of course, because of the lack of exact synchronism between independent video systems. Even when both systems are controlled from the same 60-cycle supply, rather violent horizontal motion will be present. This is the result of slight phase errors at 60 cycles/sec producing cycles of phase error at the horizontal scanning rate. In some of the tests, the two systems were placed under the control of separate crystal oscillators. This permitted the relative motion to be made uniform at about the most disturbing rate.

As the crosstalk image moves across the main picture, it appears to be framed. This frame is formed by the horizontal and vertical synchronizing pulses, and is much more noticeable than any feature in the image. Since the side frame of the image extends from top to bottom of the wanted picture, no part of the latter escapes this interference. At threshold there is no semblance of frame or image; just a slight flicker appears as the frame moves across some sensitive portion of the main picture.

The above discussion applies to undistorted, or flat, crosstalk coupling. When the coupling has a sloping characteristic, the crosstalk image will appear in bas relief. But, again, the frame having the largest rate of change, is the most prominent feature in the crosstalk image.

Apparatus and Circuit Arrangement

In Fig. 1 is shown a simplified block schematic of the test setup. The box labelled "slide scanner" represents a conventional flying-spot scanner in which the main picture signal was derived. The slide was a standard 2 × 2-in. slide of a picture called "Teacup Lady." The output signal had an amplitude of 2 volts peak-to-peak (including the synchronizing pulse) and was transmitted via a 3-way mixing pad to the viewing monitor shown on the right. The interfering picture was a test pattern known as "Indian Head." The signal for the test pattern was generated by a monoscope, which is shown in the box with the appropriate label. The output of the monoscope was also 2 volts peak-to-peak, and it was transmitted through a variable attenuator and distorting network to the mixing pad.

Synchronizing signals for the slide scanner and monoscope were obtained from independent generators. These are indicated by separate boxes labelled "sync generator." Both generators were controlled either from the same 60-cycle power source or from separate crystal oscillators.

The viewing monitor was one developed and built at Bell Telephone Laboratories. The picture tube was a 10-in. metal-backed tube (Type 1816 P4) operated at about 11 kilovolts. A d-c restorer circuit of the type usually found in television receivers was used instead of the clamper originally incorporated in the viewing monitor. "Flywheel" synchronization, which this monitor did not have, was simulated by separate synchronization directly from the synchronizing generator associated with the spot scanner.

Since the distorting network had zero loss at 4 mc, or had a loss which could be taken into account, the loss in the attenuator represented the coupling loss at 4 mc as measured between two television systems at points of equal signal level. The coupling loss at other frequencies depends on the characteristic of the distorting network.

Figure 2 shows the four loss-frequency characteristics which were used in the tests. The "flat" characteristic was simply distortionless transmission. The one labelled "6 db/octave" gave an increase in transmission of approximately 6 db for each doubling of frequency. The "12 db/octave" and "26 db/-octave" labels have similar meanings. The last-named characteristic approxi-

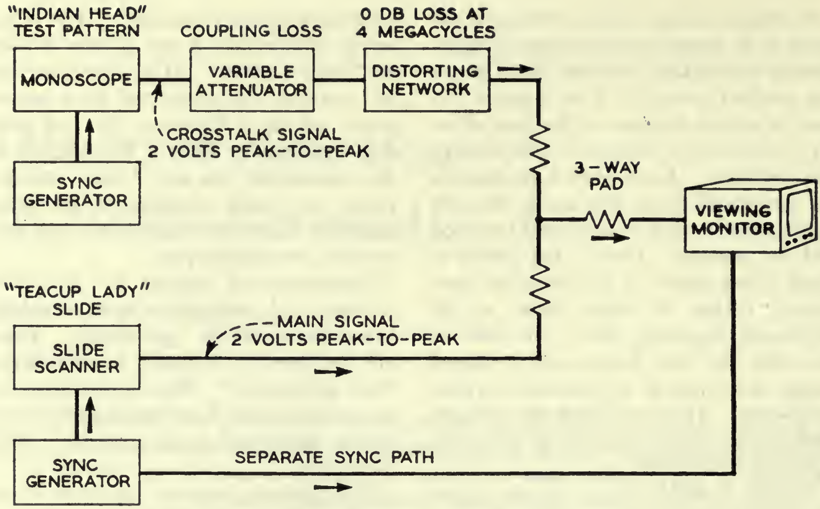


Fig. 1. Block schematic of test setup.

mates the amplitude-frequency distortion (without propagation effects) occurring in near-end crosstalk between video systems operating in local exchange areas on maximum length of line.[2]

Picture Setup and Viewing Conditions

The selection of "Teacup Lady" as the main picture for these tests was based on past experience. Its sensitivity to noise and low-frequency interference had already been established. During all tests a highlight luminance of 45 foot-Lamberts and a contrast range of 120:1 were maintained. Frequent checks on these values were made with a modified Macbeth Illuminometer.

The "Indian Head" test pattern was chosen as the interfering picture because of its high key and strong black lines. Its sudden changes from white to black tend to make its distorted image more interfering than that of most pictures.

All viewing was done in a darkened room in which the ambient light, resulting mostly from light reflected from the kinescope, was approximately 0.02 foot-candles as measured near the viewing surface.

The viewing distance was 24 in. which was four times the height of the 6 × 8-in. image.

Observers

Observers for these tests were technical and staff employees of Bell Telephone Laboratories. In each test group there were ten or more observers, some of whom were known to be rather critical, that is, intolerant of picture impairments, some less critical, and others fairly uncritical. All were experienced and were known to be reasonably stable in their judgments. They were selected on the basis of giving a fairly uniform distribution of types of observers ranging from critical to uncritical. No attempt was made to obtain a random sample of the television audience.

Testing Procedure

One observer at a time was seated directly in front of the viewing monitor at a distance of four times the picture height. The room was darkened and the observer was shown the main picture, "Teacup Lady," without any crosstalk signal added. He was told that this was the "best" picture, and that any

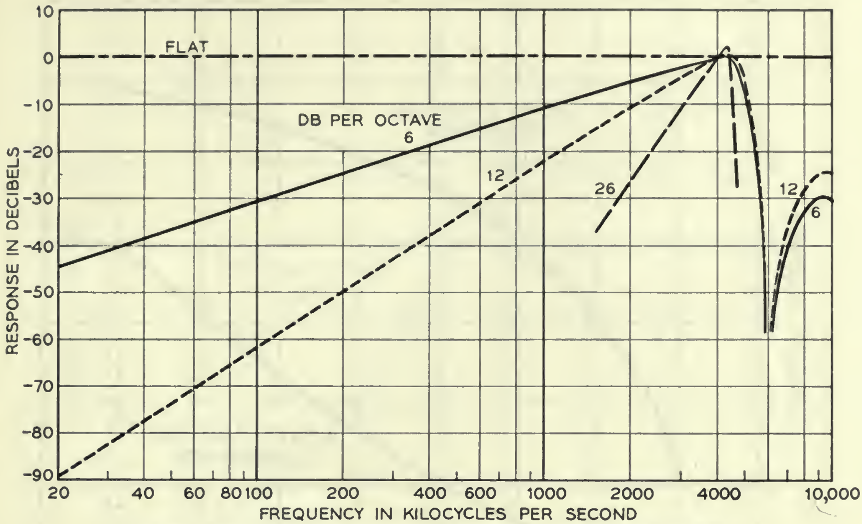


Fig. 2. Amplitude-frequency distortion in crosstalk paths.

imperfections, such as noise and the like, were to be ignored in making his subsequent judgments of picture impairments. A moderate, but visible amount of crosstalk signal was then added to the picture. The observer was told that this was the type of disturbance upon which he would be asked to pass judgment, but that the strength of the interference would probably be different for each test condition.

The observer was given a list of seven numbered comments from which he was to select the one which best described his reaction to, or his rating of, the crosstalk present in each test condition. These comments were as follows:

1. Not perceptible;
2. Just perceptible;
3. Definitely perceptible, but only slight impairment to picture;
4. Impairment to picture, but not objectionable;
5. Somewhat objectionable;
6. Definitely objectionable; and
7. Extremely objectionable

The comments are arranged in logical order, progressing step by step from "not perceptible" to "just perceptible" through various degrees of adverse reaction to "extremely objectionable." The comment numbers are used, not only as indentifications of the various comments, but also as a scale of observer reactions. Special mention will be made in later discussions of comments No. 2 and No. 4: the former signifies the near threshold value of crosstalk for the observer; the latter is the severest comment which can be made without rating the crosstalk as objectionable.

At each sitting, the observer rated from 16 to 22 levels of crosstalk. The levels covered a range of 28 db, subdivided into 4-db steps. Each level appeared twice, and in some tests, three times in the series. All observers were shown precisely the same series of levels. The presentation of levels was in random order; use of Tippett's *Random Sampling Numbers*[3] was made for this purpose.

As each test condition was presented, the observer called out the number of the comment which best described his reaction to the level of crosstalk present. Separate tests were made for each type of distorting network in the crosstalk coupling path.

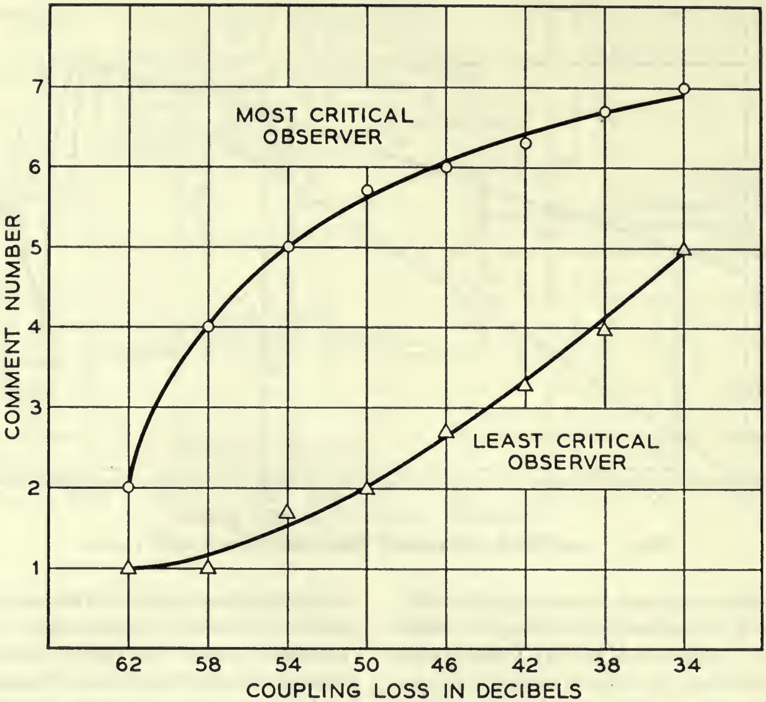


Fig. 3. Reactions of individual observers to flat, lumped crosstalk.

Test Results and Interpretation of the Data

Observers apparently use the comment numbers as a scale of their reactions. This will be seen in Fig. 3 where, for purposes of illustration, are plotted the reactions of only two observers to flat, lumped crosstalk. The flat coupling loss is given by the abscissas which indicate stronger crosstalk to the right; comment numbers are indicated by the ordinates. The data points shown are the averages of three judgments of the same indicated crosstalk level submitted to the observer. Only in rare instances did an observer waver by more than one comment in rendering his judgment of a given level of crosstalk. The curves for other observers, in general, fan out between the two curves shown. Occasionally, however, some of the curves cross. This means, for example, that the most critical observer may not be the same observer over the entire range of crosstalk levels. For this reason it was decided to pool the data of all observers and pick out the critical, median and uncritical responses characterizing the reaction of the group. This treatment of the data is illustrated, in part, in Fig. 4.

Figure 4 shows the distribution of the comments selected by the entire group of observers in response to various levels of flat, lumped crosstalk. The numbers at each of the marked lattice points represent the totals of votes cast for the indicated comment number at the given level of crosstalk. In this test 10 observers made three judgments of each level of crosstalk except that for 62-db coupling loss where only one judgment was made. Accordingly, the total of the lattice point numbers is 30 in each column, except that for 62-db, where the

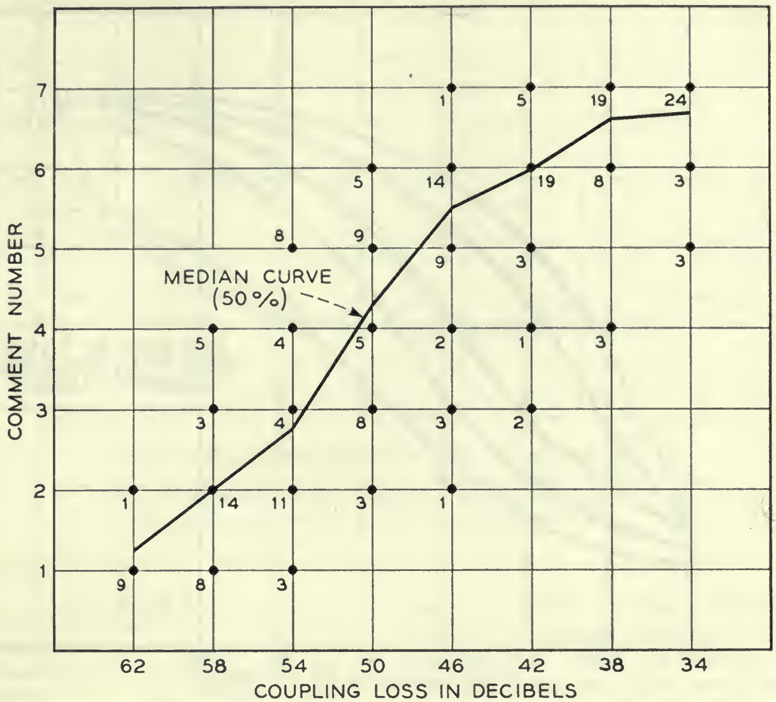


Fig. 4. Distribution of comments from 10 observers (flat, lumped crosstalk).

total is 10. From this display of the data, one can see that when the coupling loss was, say 54 db, there were 3 votes for comment No. 1, 11 for comment No. 2, 4 for No. 3, 4 for No. 4, and 8 votes for No. 5.

The data shown in Fig. 4 can be further classified by drawing in, for example, the curve (or broken line) below and above which 50% of the votes fall. This is shown in Fig. 4 as "median curve." To avoid ambiguities in the count of votes, it was assumed that the votes for each comment were spread uniformly over a range of plus or minus one-half of a comment number; at the ends of the scale, where there could be no comments less than No. 1 or greater than No. 7, the spread was assumed to be only one half as much.

In a similar way, other contours, below which a given percentage of the votes fall, can be drawn. This was done for several different percentages as shown in Fig. 5. These contours pertain to the same group data shown in the previous figure. The computed values are shown as dashed broken lines. The heavier smooth curves were drawn in more or less by eye to show the general trends for engineering purposes. It will be rather evident that the 90% contour corresponds to a curve for a critical observer, the 50% contour to one for a median observer, and the 10% curve to an uncritical observer. As mentioned earlier, these contours do not necessarily represent the reactions of any individual observers.

The contours of Fig. 5 show that a fairly uniform distribution of types of observers was obtained; there is no pronounced bunching of the contours. Looking now at the 90% contour, which

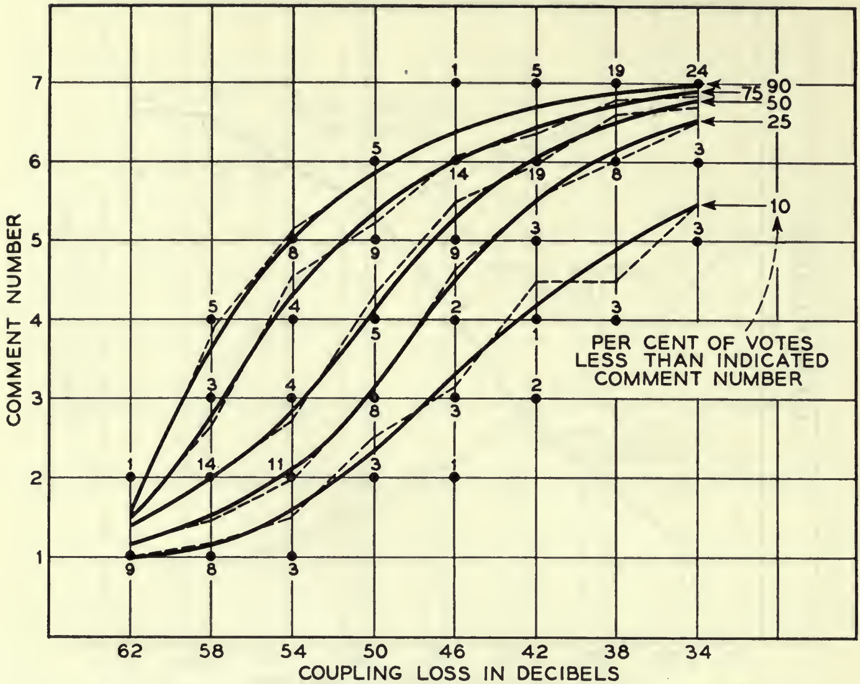


Fig. 5. Distribution contours of comments from 10 observers (flat, lumped crosstalk).

represents the reactions of the "composite" critical observer, it is seen that the crosstalk is just perceptible to him when the coupling loss is about 61 db and that he still does not object to it (votes no more than comment No. 4) when the crosstalk is made 4 db stronger. The median observer finds the crosstalk just perceptible at 58 db loss; and the uncritical observer does not notice the crosstalk until the coupling loss is reduced to 52 db.

One of the main objectives of this study of the reactions of observers to crosstalk was to arrive at a tolerable limit for the crosstalk coupling loss. The contours of observer reaction, as just discussed, will serve as a useful guide in this connection. As a criterion for tolerable limit, it is proposed that the crosstalk not exceed a value which is either objectionable to the most critical observers, or more than just perceptible to half of the observers. Referring to the contours of Fig. 5, it is seen that a coupling loss of 58 db evoked comment No. 2 from 50% of the observers and less than comment No. 4 from the most critical observers. The limiting coupling loss is, accordingly, 58 db for flat, lumped crosstalk.

The test results for the sloping types of coupling and for both synchronous and nonsynchronous operation of the video systems are very similar to those discussed in detail for flat coupling. They differed mainly in the values of coupling loss at which the comments occurred and, to some extent, in the steepness of rise of the contours. Rather than a display of separate matrices and contours for each of the tests, a summary of the responses of the critical and median composite observers is presented in Table I which follows.

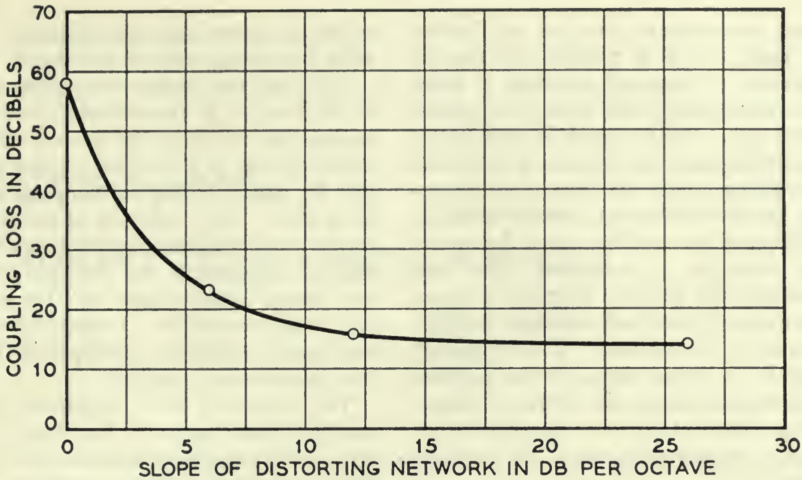


Fig. 6. Four-megacycle coupling loss at which 50% of observers vote "just perceptible."

Table I

Coupling network distortion	Coupling loss, in decibels, at 4 mc		
	A	B	C
Flat* (1)	61	57	58‡
Flat† (2)	60	55	57.5
6 db/octave*	27	22	23‡
12 db/octave*	17.5	10.5	11.5
12 db/octave†	19	14	15.5‡
26 db/octave*	20	12	14‡

Column A: Critical observers rate "just perceptible" (comment No. 2)
Column B: Critical observers rate "impairment to picture, but not objectionable" (comment No. 4)
Column C: Median observers rate "just perceptible" (comment No. 2)

* Nonsynchronous: crosstalk image moves left to right at rate of 2 frames/sec.
† Synchronous: crosstalk image moves erratically back and forth across the main picture.
‡ Selected as the limit for the indicated type of crosstalk coupling.

Discussion of Results

One of the most striking aspects of the results tabulated above is the large change in required coupling loss in going from flat to sloping distortion in the coupling path. Since the sloping network emphasizes the higher frequencies at the expense of the lower, the former must contribute very little to the interfering effect of the crosstalk image. This seems a reasonable conclusion when it is remembered that the high frequencies contribute to fine detail and sharp edges, neither of which is very apparent in the faint and moving crosstalk image.

To show the change in requirement with changes in slope of the coupling characteristic, the values marked ‡ in Table I have been plotted in Fig. 6. Here the abscissas represent the slope of the coupling characteristic in decibels per octave of frequency; the ordinates indicate the required coupling loss in decibels at 4 mc. It will be noted that the major portion of the reduction in requirement takes place within the first 6 db per octave; and that the requirement appears to approach an asymptotic value.

Despite the easing of requirements by as much as 35 to 44 db in going from flat to sloping couplings, it is more often the

latter requirements that are the hardest to meet. This is particularly true in instances of near-end crosstalk in cable circuits carrying video signals in opposite directions. As the length of cable to the nearest repeater, or terminal, is increased, two things occur: the level of the incoming signal is decreased and the steepness of slope of the equalization of the receiving amplifier is increased. The first increases the effective coupling between circuits and the second increases the high-frequency transmission of the crosstalk signal. The end result, for the particular case under discussion, is that the maximum length of circuit is limited by the 14-db requirement for 26-db/octave slope.

The differences between the results for synchronous and nonsynchronous operation are not significantly great. As implied earlier, the term "synchronous" is a misnomer, and actually means erratic motion rather than uniform motion of the crosstalk image. For the flat crosstalk tests the difference was trivial; for the 12-db/octave case a difference of 4 db obtained.

All the above results, it should be noted, were obtained for lumped couplings between circuits carrying the wanted and unwanted picture signals. This results in a reasonably clear unwanted picture, which aids in its detection and imposes rather severe coupling requirements. Where the coupling is distributed over a long distance, as in adjacent pairs, the crosstalk image will be less clear and probably somewhat less severe requirements would be imposed.

Recapitulation

Tests were made to determine how much video crosstalk can safely be tolerated in black-and-white television pictures. Artificial crosstalk coupling with four different loss-frequency characteristics was used. In using lumped, rather than distributed, coupling more conservative requirements were obtained. The degree of synchronization was controlled to insure that approximately the most disturbing conditions obtained.

The disturbed picture was one known to be sensitive to interference; the disturbing picture was a test pattern which probably was as disturbing as any picture for both the flat and sloping coupling tests. The rendition of the main picture received considerable care: the highlight brightness and contrast range were better than average, and the noise was barely noticeable. Frequent checks were made to keep the quality of the picture reproduction constant.

The observers were experienced in judging impairments of television pictures, and were known to be stable in their judgments. The conditions of observation were controlled in the matter of ambient light and viewing distance.

The results obtained from these tests and proposed as limits for the several types of crosstalk coupling are somewhat conservative. The crosstalk resulting from these values of coupling could not be detected by about half the observers and were not rated as objectionable by the most critical.

Acknowledgments

The author acknowledges his indebtedness to H. N. Christopher, who was a close associate in conducting the experiments; to J. M. Barstow, under whose direction the work was done; and to Pierre Mertz, technical advisor to the project, who suggested the testing technique.

References

1. P. Mertz, A. D. Fowler and H. N. Christopher, "Quality rating of television images," *Proc. I.R.E.*, vol. 38, pp. 1269–1283, Nov. 1950.
2. L. W. Morrison, "Television transmission in local telephone exchange areas," *Jour. SMPTE*, vol. 56, pp. 280–294, Mar. 1951.
3. L. H. C. Tippett, *Random Sampling Numbers*, Cambridge University Press, London, (Tracts for Computers, XV), 34 pp., 1927.

Ultra-Speed Theater Television Optics

By L. T. SACHTLEBEN and G. L. ALLEE

The general properties of a reflective optical system of the Schmidt type are discussed, with particular reference to practical considerations of design and application in the theater. The relationships of focal length, projection distance and incident screen illumination are illustrated. Also discussed are the factors on which resolving power and fine-detail contrast depend. Some facts relating to the design, material and application of the aspheric or ogee lens are given.

The problem of satisfactorily projecting a kinescope image upon an external screen has concerned television engineers for many years. Early attempts were made with ordinary projection or photographic lenses of both domestic and European origin. The difficulties were many and serious, and were never completely overcome. One of these was that the face of the kinescope had to be flat or even concave toward the lens, because of the shape of the image surface of the lens. Such shapes are not good from the standpoint of the electron optics of the kinescope, and they are not good mechanically, especially if the tube is large. Added to this was the practical impossibility of getting a lens that would pick up enough light from the kinescope to produce a magnified screen image of adequate brightness and size for theater use. The kinescope image is low in candlepower per unit area compared with the tungsten and arc lamps used in the usual motion picture projectors. As a result, the light from it has to be gathered much more efficiently than in usual projectors. In other words, the projection optics must have much more speed for theater television projection than for motion picture projection from film.

The answer to the need for an ultra-speed system began to take form in the middle 1930's. Donald O. Landis, an optician and designer and maker of telescopes, got the idea that the new high-speed Schmidt astronomical telescope could be used for projection television. This instrument covered a wide field at efficiencies ranging five to ten times greater than the best available lenses. Also, it *required* the face of the kinescope to have the convex shape

Presented on October 15, 1951, at the Society's Convention at Hollywood, Calif., by L. T. Sachtleben and G. L. Allee, Advanced Development Engineering, RCA Victor Division, Camden, N.J.

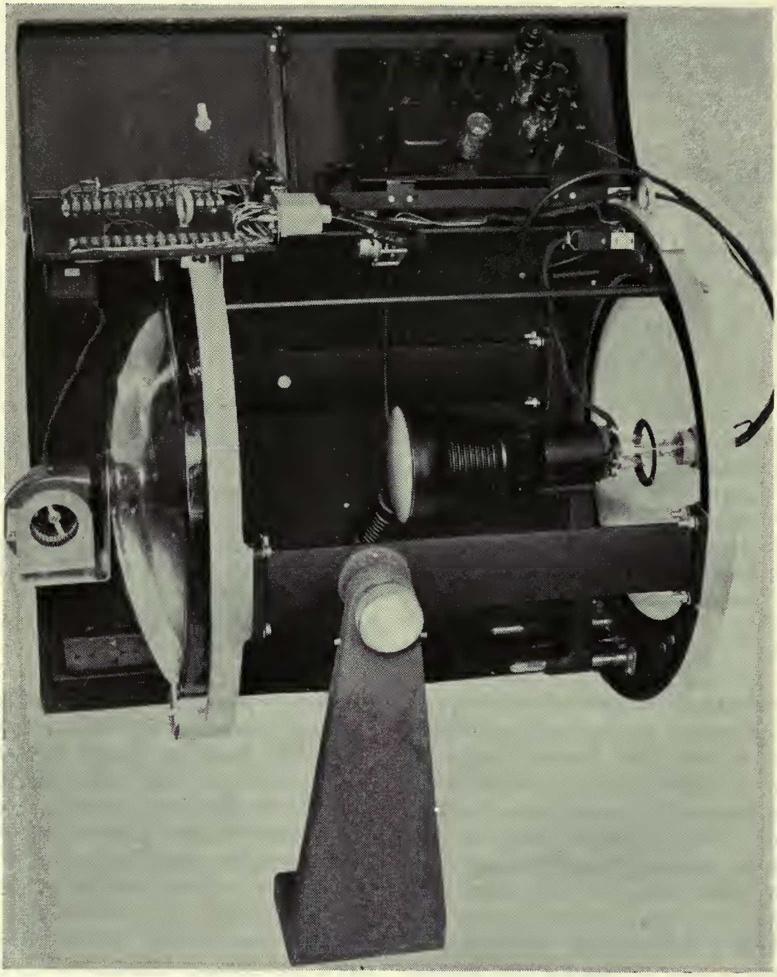


Fig. 1. RCAPT-100 Ultra-Speed Projection System.

which is normal in kinescope design. Landis, working in the RCA television laboratory, built the first model ever made that proved that the optics of the Schmidt telescope could be modified to project sharp and brightly illuminated television images. Working with E. G. Ramberg and I. G. Maloff, he also constructed the first ultra-speed optical system of this type for theater television projection,[1] and the first patent on the adaptation of the Schmidt optics to television use was issued to him.[2] Many of the practical problems of optical design and economical construction were later worked out by D. W. Epstein and I. G. Maloff who also applied the Schmidt optics to home receivers.[3–5]

The theory of reflective optical systems of this type has been extensively discussed elsewhere.[6,7] This paper will be restricted to practical aspects of the system

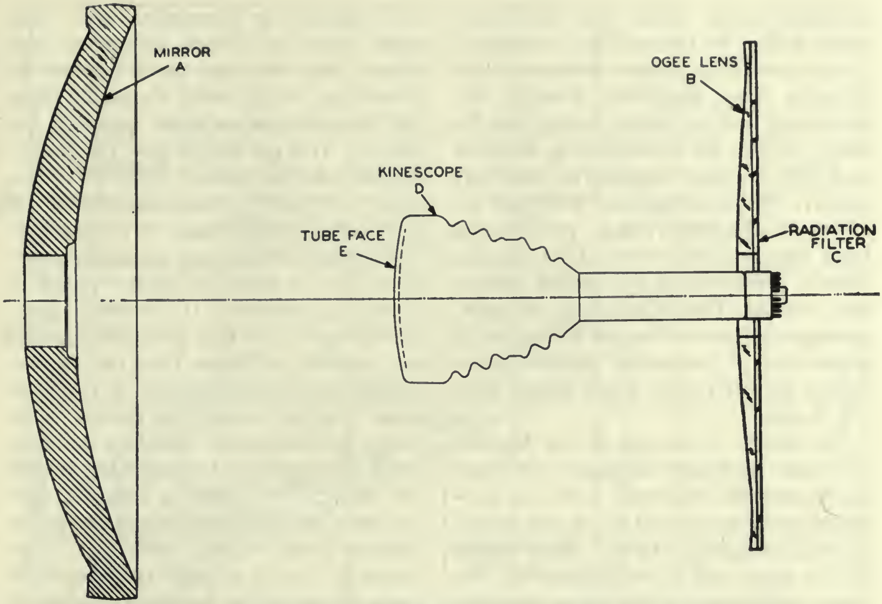


Fig. 2. Schematic of RCA Ultra-Speed Projection System.

which may be of interest to applications engineers and exhibitors.

Nature and Performance of the Ultra-Speed System

The RCA Ultra-Speed Theater Television Optics (Fig. 1) are currently being built in a focal length of 15.515 in. and an effective optical speed of $f/0.82$.* This is a suitable focal length for a large number of theater installations where pictures up to 15 × 20 ft are to be projected from a 7-in., 80-kv kinescope. The system is capable of delivering a 2-ft-c highlight level to the screen under these conditions, from kinescopes of present design.

The optical system has two basic optical parts: a concave spherical mirror; and a low-power ogee lens at its center of curvature. In its meridian section the curved surface of the lens is seen to have a generating curve in the form of an S or ogee, hence the name. These parts are shown, respectively, at A and B of Fig. 2. The focal length of the ogee lens is of the order of 20 times that of the entire optical system. If the ogee lens is not made of a suitable flint glass, a radiation filter must be mounted approximately in contact with it as shown at C of the figure. Such a filter becomes, of necessity, a part of the optical system and its surfaces must be made sufficiently flat and parallel to have the minimum possible effect upon the image. The kinescope tube is located at D on the axis of symmetry of the optical system, with its face, E, directed toward the mirror. When the radius of curvature of the kinescope face or screen is equal to the focal length of the optical system (of the order of one-half the radius of curvature of the spherical mirror), the

* A System that gathers a cone of light 90° in diameter has a speed of $f/0.71$. In a theater television projection system, the mirror must be masked out at the center to prevent reflection of light directly back to the face of the kinescope. Taking this into account, the Ultra-Speed System has a net optical speed of $f/0.82$.

kinescope image will lie in a flat surface where it may be received and viewed on a conventional flat motion picture screen. As with other projection systems, the distance to the projection screen may be freely chosen, the system being adapted to a wide range of distances as described below. Projected picture size will be substantially proportional to distance from tube face to screen. It is also inversely proportional to optical system focal length. For all practical purposes, curvature of the kinescope screen is independent of projection distance providing optical system focal length does not change.

The design of the ogee lens is dependent upon projection distance. Its ogee curve must be "tailored" to fit the particular magnification at which the optical system is intended to work. The purpose of the ogee lens is to compensate for certain inherent qualities in the imagery of the outlying portions of the spherical mirror, and the needed compensation changes with projection distance. The lenses supplied with the systems are carefully designed to suit the distance from projector to screen. The focal length of the optical system remains unchanged when lenses are changed to take care of a series of projection distances.

In manufacture, the ogee lens is given its shape by a master surface. The exact methods used depend upon the material chosen for the lens. Sagging or "dropping" methods are used with glass, casting with thermosetting materials, and pressing with thermoplastic materials. Whatever the material, preparation of the master surface and the process of forming the lens are carried out with great care. The lenses are made by the best techniques that it has been possible to develop.

At the present time the Ultra-Speed System uses only glass lenses, since they are the best obtainable. There is every reason to expect lenses to be made just as well from plastic materials, and it is anticipated that suitable techniques will be developed to accomplish this. The glass lenses are more expensive than plastic, but they are more resistant to scratching, and if made of suitable glass, will also serve as radiation filters for the system. It is not known how the quality of glass and plastic ogee lenses will eventually compare, but the prospect of lower cost makes plastic lenses very attractive.

The ogee lenses must be applied economically in order to keep equipment cost at a minimum. It is readily appreciated that there is a practical limit to the number of lenses that can be designed, made and stocked in order to adapt a given ultra-speed system to the range of projection distances encountered in theaters. It would be absurd, for example, to make a separate ogee lens for each 1-ft increment of projection distance between 40 ft and 70 ft. Fortunately, there is a rather large practical range of projection distances at which a given ogee lens may be used by merely focusing the system accordingly. This range is observed to extend from about 10% more than ideal design distance to about 15% less. Additional flexibility results from changing kinescope raster dimensions electrically. An extensive range of picture sizes, as well as projection distances, is therefore available with a projection system equipped with a single ogee lens. Two different lenses will adapt the projection system to a large range of projection conditions as illustrated in Fig. 3.

The amount of light received by the optical system from each unit of area on the kinescope screen depends on the angular diameter of the cone which the optical system effectively subtends at the faceplate. In the Ultra-Speed System this angle is approximately 90° for maximum efficiency consistent with best image quality. It is obvious that if this light is projected into a small picture a brighter screen will result than if it is projected into a large picture, because the total light available is approximately constant. At long throws, a given optical

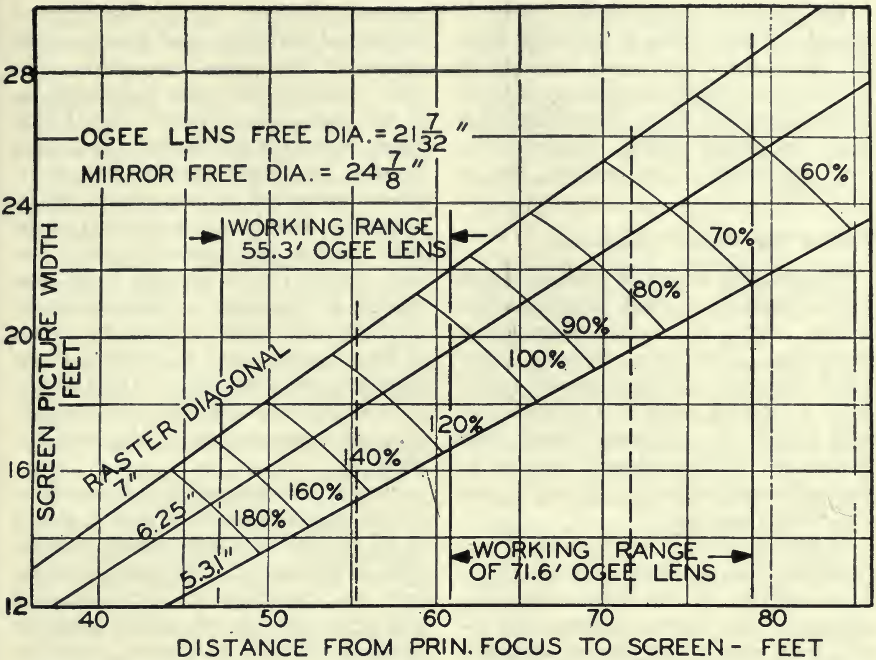


Fig. 3. This illustrates range of projection distances available with the 15.515-in. focal length Ultra-Speed System by use of ogee lenses designed for ideal projection distances of 55.3 ft and 71.6 ft. It also illustrates range of picture sizes available by varying kinescope raster diagonal between 5.31 in. and 7.0 in. Curves of constant illumination indicate available range of screen illumination levels, based on a level of 100% at 62 ft from a 6.25-in. diagonal raster. This level is about 2 ft-c in the highlights with currently available kinescopes.

system will produce pictures at lower illumination levels because the pictures are larger. This can be controlled to a limited extent by electrically varying the raster dimensions in inverse relation to the throw. An increase in throw will then be attended by a decrease in raster area. But, since the beam power is not reduced, the raster brightness increases. By this means, pictures can be kept at approximately constant size and brightness over a considerable range of projection distances. For example, it is seen from Fig. 3 that the projection distance can be varied between 57 ft and 67.6 ft with no change in picture size and with an illumination variation of only 10% from the average. Also, picture widths can be varied between 17.2 ft and 22 ft with no change in projection distance and only a 10% illumination variation from the average. When the ogee lens is changed, and a new range of projection distances is entered, the choice of picture brightnesses and sizes available with the particular lens is, of course, altered. In order to have the above-described ranges of projection distance and picture size available with a single ogee lens, the lens would have to be designed for an ideal working distance of about 63 ft. The ogee lenses used with this system are presently being made for an ideal projection distance of 62 ft. Future installation requirements will determine the choice of additional lenses.

The present Ultra-Speed System is capable of delivering a highlight level of 2 ft-c to the screen, when focal length is 15.515 in., projection distance is 62 ft, raster diagonal is $6\frac{1}{4}$ in., magnification is $48\times$ and anode voltage is 80 kv on a 7-in. kinescope. The picture size is 15×20 ft.

Factors That Limit Performance

Performance of optical systems of this type is limited in many respects, chief among which are image illumination uniformity, large-area contrast, fine-detail contrast, resolving power, maximum projection angle and efficiency of light utilization. To some extent these factors are all interrelated, and tie in also with such factors as optical system size, weight and cost.

In general, the projected images equal or exceed those projected from film, from the standpoint of flat illumination distribution. The flattest illumination results from making the mirror considerably larger in diameter than the minimum required to fill the ogee lens with light from the center of the raster. This rapidly increases size, weight and cost of the mirror, however, and it has been found practical to limit the mirror diameter to about 10% in excess of this minimum. Illumination at the sides of the picture exceeds 80% of the center at a magnification of $48\times$.

Large-area contrast depends upon design factors, quality factors and maintenance factors, because all of these influence the amount of stray light (light not directed to formation of the desired image) that emerges from the system to generally dilute contrast. Stray light also includes light returned to the kinescope screen by the system or by the projection screen. Design factors include surface coating of ogee lens (and radiation filter, if used), central blocking of the mirror, presence or absence of a radiation filter, finish of mechanical parts, etc. Quality factors include workmanship on all reflecting and refracting surfaces, quality of surface coatings and all optical materials, and quality of all surface finishes inside the system. The chief maintenance factor is summed up in one word, "cleanliness." The Ultra-Speed System is capable of a large-area contrast of approximetely 100 to 1. This is measured by projecting a special uniformly illuminated test object of the same area as the kinescope raster, but with about 1% of its area black and opaque at the center. Light levels are measured within and without the image of this opaque area to determine the large-area contrast ratio. The 100-to-1 ratio amply insures against "graying out" of small shadow areas in high-key pictures.

Fine-detail contrast is influenced by factors that limit resolving power, as well as by general stray light which is negligible as just shown. For example, if the light that should go into the image of a grid of equally spaced parallel lines becomes uniformly distributed over the image of the grid, the contrast becomes unity and the lines are not resolved at all. Any optical loss of fine-detail contrast is primarily due to imperfections in the imagery of the optical system. This may be due to manufacturing imperfections in the optical parts, or their misadjustment, and may also be due to lack of refinement in the optical design. All these factors may contribute at the same time.

It has proved practical and economical to finish the spherical mirrors so that their effect on fine-detail contrast is entirely negligible. The manufacturing imperfections most responsible for limiting fine-detail contrast are to be found in the ogee lens. These imperfections consist mainly of very small ripples or "zones" in the ogee surface of revolution, and also in failure of the surface to be purely one of revolution. The greatest care is taken in manufacturing to keep such errors at a minimum and methods are now being improved as rapidly as possible.

In the present ultra-speed optical systems with flint lenses, the fine-detail contrast ratio at 600 lines per picture height ranges between 2.0 and 3.0. The present goal is to raise this ratio to 10. The contrast ratio changes rapidly with line number and at 200 lines per picture height it ranges from 30 to 60. While contrast ratios of 2.0 and 3.0 at 600 lines do not satisfy development and commercial engineers, the appearance of 600-line detail at a normal viewing distance of $1\frac{1}{2}$ screen widths is well above the point where it would be a serious commercial limitation at the present time.

When the ogee lens is made of a single peice of glass, fine-detail contrast is limited by chromatic aberration. The effect of this can be reduced somewhat by making the ogee lens of low-dispersion crown glass instead of flint. A flint filter screen then has to be used, and unless it is finished with great care, its two surfaces can more than offset any improvement to be realized from the crown glass. Chromatic aberration effects can be further offset by a change of magnification. The use of a larger kinescope with shorter projection distance will make the chromatic effects smaller in relation to the size of the picture. It is estimated that the use of crown glass in place of flint, and of a 10-in. kinescope in place of the 7-in., can relatively reduce the area of the chromatic confusion disk a maximum of 80%. Another approach is to make the ogee lens of two different glasses and development work is proceeding along this line. This may involve manufacturing complications, and result in a more expensive lens. It is too early to predict the practical outcome of these approaches to the problem.

Any increase in kinescope size involves an increase in projection angle. This is attended with some increase in vignetting, and also with a tendency toward reducing detail contrast and resolution at the corners and edges of the picture. The vignetting, however, tends to retard the loss in contrast and resolution at the expense of brightness in the outer portions of the image. In general, it can be said that, unless an increase in the size of the kinescope will yield an improvement such as suggested above in connection with the effect of chromatic aberration on fine-detail contrast, there is little or nothing to gain optically by choosing wide-angle projection. If the power in the kinescope beam could be increased in direct ratio to the raster area, the story would be quite different, but in present kinescopes this cannot be done. The conversion efficiency of the phosphor increases a moderate amount when the raster area is increased, but an increase in kinescope size usually results in reduced screen brightness for a given projected picture size when using an ultra-speed optical system of given focal length.

The factors that influence fine-detail contrast also largely determine limiting resolving power. When flint lenses are used, the limiting resolution of the ultra-speed system is 1200 television lines per picture height, or better, in all parts of the picture. It exceeds 1800 lines in the center, and the television scanning lines are clearly reproduced throughout the picture. The present goal is a limiting resolution of 3600 lines.

Proper location of parts is essential to good resolution and detail contrast in the image. All parts of the assembly are carefully made to insure accurate locations, and adequate adjustments are provided for locating the kinescope with reference to the optical parts. The center of curvature of the faceplate must be on the axis of the optical system, and installation and maintenance engineers are provided with means of testing to insure that the adjustment is properly made. Special installation and maintenance tests are also made to insure that the axis of the ogee lens is adjusted to pass through the center of curvature of the mirror.

It is obvious that an optical system of this type can be increased in efficiency up to the point where it gathers all the light that the kinescope is capable of radiating into a hemisphere. However, image quality falls off, and weight, size and cost increase as more light is gathered. All things considered, efficiency is at a practical maximum when the system gathers only the light within a cone of approximately 90° diameter, which is about one-half the light radiated. Other losses due to tube-blocking, obstruction of light by mechanical parts, absorption by the mirror, and reflection losses at lens surfaces bring the efficiency of light utilization down to about 30%, depending upon kinescope diameter. This is still about five times the efficiency of an $f/2$ projection lens.

When the ogee curve of the lens is modified to take care of projection distance changes in excess of a nominal 10% to 15%, the diameter of the lens must change also. The change is greatest in the range of low magnifications. From 5× to 10×, the ogee lens diameter increases about 20%. From 10× to 20×, the increase is about 9%. Between 20× and 40×, it increases only about 5%. The ultra-speed system requires lenses of the largest size because it operates at high magnification in the theater.

The ogee lenses supplied with these systems have been very carefully computed to make the system completely free of spherical aberration at the center of the picture, where it is most desired to have maximum detail and contrast. Also, care is taken to balance the chromatic aberration inherent in the lens in such a way as to minimize its effect on contrast and avoid the appearance of color in the picture. The effects of the thickness and curvature of the faceplate of the kinescope are taken into account in the computations. The design of each lens is carried through with the greatest possible care and many computational checks are made on the completed design to insure against errors that would spoil the shape of the lens. Manufacture of the lens is based upon coordinates computed at radial intervals of 1 mm, or for about three hundred zones in the case of the 15.515-in. focal length system. Care of this order is carried right on through the processes of lens manufacture. The good performance of the ultra-speed system depends upon the greatest care being taken in design and production of the ogee lens.

The high limiting resolution of 1200 lines or better over the entire picture is an indication of the extreme flatness of the image produced by this system. This is especially emphasized by the fact that the depth of focus of a system of this speed and range of magnifications is very small at the screen. A movement of the screen of 3 or 4 in. will cause marked defocusing of the image and loss of detail contrast and resolution. As a result of this limited focal depth, not only must the curvature of the image be very small, but the system must be carefully installed to insure that the axis of projection is at right angles to the screen. Very little tilt of the screen away from its optimum position is permissible.

In closing, the writers would like to acknowledge the efforts of all who have in any way contributed to the successful performance of this optical system, especially those of D. W. Epstein, I. G. Maloff, D. J. Parker, G. L. Dimmick, J. E. Volkmann and R. V. Little, Jr., of the Radio Corporation of America, and personnel of the American Optical Company at Southbridge, Mass.

References

1. I. G. Maloff and W. A. Tolson, "A résumé of the technical aspects of RCA Theatre-Television," *RCA Rev.*, vol. 6, pp. 5–11, July 1941.
2. U. S. Pat. 2,273,801; filed Dec. 30, 1938.
3. I. G. Maloff and D. W. Epstein, "Reflective optics in projection television,"

Electronics, vol. 17, pp. 98–105, Dec. 1944.
4. D. W. Epstein and I. G. Maloff, "Projection television," *Jour SMPE*, vol. 44, pp. 443–455, June 1945.
5. I. G. Maloff, "Optical problems in large-screen television," *Jour. SMPE*, vol. 51, pp. 30–36, July 1948.
6. *A Bibliography on Reflecting Optics — Covering the Period 1925–1950*, Published by Armed Forces—National Research Council Vision Committee (Secretariat, 304 West Medical Building, University of Michigan, Ann Arbor, Mich.).
7. "Theater Television bibliography," *Jour SMPE*, vol. 52, pp. 268–272, Mar. 1949.

Discussion

Dr. F. N. Gillette: What is meant by the term "ogee"?

John E. Volkmann (*who presented the paper*): According to the dictionary, the name "ogee" is applied to an object having an S-shaped profile. Because a radial section of the lens clearly has such a profile, the name is obviously applicable. This type of lens has been variously called a "corrector plate," a "corrector lens" and an "aspheric lens." It is felt that the name "ogee" lens is more descriptive of the form of the lens than any of the older terms, and has the advantages of shortness and phonetic simplicity.

Dr. Gillette: A further point, I think I heard an implication that by changing the design of the ogee lens you could change the focal length in some appreciable quantity. Is that correct?

Mr. Volkmann: The focal length of the optical system remains unchanged when the ogee lenses are changed to take care of a series of projection distances, unless a change is made in the radius of curvature of the concave mirror.

Dr. Gillette: It just has been my impression that the ogee lens contributed very slightly to the net focal length of the whole system, and consequently I would be very much interested in learning your method whereby changing that lens would change the total focal length appreciably.

Mr. Volkmann: The ogee lens plays only a small part in determining the net focal length of the whole optical system, as you suggest. The curvature of the concave mirror largely determines the net focal length of the system.

Mr. Strickland: Is the barrel sufficient shield for radiation to prevent physical harm?

Mr. Volkmann: I presume you are referring primarily to the x-ray radiation effects?

Mr. Strickland: Yes.

Mr. Volkmann: The barrel is completely shielded, not only with respect to the metal parts themselves, which are fully lined with the proper thickness of lead, but, as explained, the radiation filter is a glass that cuts down the x-ray radiation so that the unit is completely protected and meets all the Underwriters' requirements with regard to x-ray shielding.

A. D. Fowler: You mentioned that the optical system presently controls the fine-detail contrast. I'd like to know about the spot size on the projection tube itself. Is it any worse or better than a kinescope receiver? Do you know that? Is it so much better that it's only the optical parts that control the fine detail?

Mr. Volkmann: Limiting resolution of the 7-in. projection kinescope spot is approximately 700 TV lines. There is usually no trouble resolving the monoscope test pattern. This pattern has a resolution wedge that extends to 500 lines. The projected fine detail contrast is the resultant of contrast in the kinescope and in the optical system. The figures given in this paper refer to the optical system only. The contrast would not be as good if the effects of the kinescope were included.

Independent Frame—An Attempt at Rationalization of Motion Picture Production

By LT.-COL. G. R. STEVENS, O.B.E.

To reduce the cost and improve the efficiency of motion picture production, the Independent Frame technique, sponsored by the J. Arthur Rank Organization of Great Britain, aims at a flow system of production. This method, which has had marked success in a series of experimental films, now is being developed for use with television cameras and for remote direction and editing.

The problem of costs always has haunted the motion picture industry. The production of a picture abounds in loose ends and although many attempts have been made to improve on this state of affairs almost all of them have failed. A popular concept of economy has been to take the script, hack some scenes out of it and so save shooting time. Needless to say, this process in itself results in additional confusion.

For a number of years it has been apparent to some people within the industry that more thought should be given a particular production before it reaches the studio floor. The studio floor is an expensive place to think, because it costs a lot of money to have a cast and crew stand by while lighting, camera angles, last-minute costume changes and even the placement of properties are decided on.

In other lines of business it has been possible to circumvent such misadventures. Modern industrial technique is based on the theory that nothing ever need be out of place and that it is possible to eliminate human errors as cost factors through the establishment of assembly-line production methods. The lack of long-term preplanning and the absence of the orderly procedure of the assembly line is what has made the production of motion pictures such a wasteful and costly process.

Such thoughts as these revolved in the mind of a young Englishman named David Rawnsley, a set designer in one of the British studios. In the course of designing and building the sets for more than 200 films, he had ample opportunity to observe the costliness and waste of motion picture production routines. He wondered if the crowded stages, the interminable delays, the chopping and the changing, the noise and the con-

Presented on April 30, 1951, at the Society's Convention at New York, by Lt.-Col. G. R. Stevens, O.B.E., 144 Strathern Ave., Montreal West, Canada, upon behalf of Television Film Productions Ltd., London, England.

fusion, and the other uneconomic aspects of motion picture production were really necessary. By 1944 he thought he saw a way out, a method by which modern industrial assembly-line technique could be applied to film production.

He put his ideas before J. Arthur Rank and was invited to become Head of the Research Department of that organization. He was given generous facilities for experiment and in the next four years spent roughly the equivalent of $3,000,000. By the end of that period, the broad outlines of a new method of motion picture production had emerged; whereupon, Rawnsley formed Television Film Productions Ltd. to act as consultants on the processes which he had devised. The Pinewood Studio was re-equipped for experiment, and the J. Arthur Rank Organization authorized a series of films to be produced by Rawnsley's methods.

There was nothing experimental about these first productions under the new technique. They were full-budget pictures with costs based on normal production methods. The earliest picture to be placed in work was given a budget of $600,000 and those which followed were in the same cost bracket.

The J. Arthur Rank instructions to Rawnsley were rigorous. His processes had to justify themselves not by slight, but by marked economies. The completed films had to be not only equal to, but better than, standard productions, both in technical and artistic values. Above all else, the new processes had to justify themselves by simplifying the routines of production; by proving that it is possible to make motion pictures of high quality with less trouble, with less waste of time and with less expenditure.

Independent Frame and Live Action

Rawnsley called his process Independent Frame. He regarded everything but the actors as the frame of the film picture. The sets, the properties and perhaps most important of all, the perspectives, were to be built as a unit, transported as a unit, set as a unit and struck as a unit. His settings, his properties and his vistas would be put in place, would be used, and afterward would be removed in from one-tenth to one-third the time expended in ordinary stage preparations. In addition, a good many of the stage settings would be dispensed with entirely through the extended use of back projection as well as other special effects and lighting processes.

Thus, in Rawnsley's plans, there would be two partners in production — the Independent-Frame partner and the Live-Action partner. Neither would interfere with the other. Instead, they would keep out of each other's way and so save time and money.

The first necessity was a certain amount of reconstruction in Pinewood Studio. Twin stages were built, each 200 by 175 ft in area, with a collapsible insulated partition between them. The studio area beyond the stage was arranged on the assembly-line principle. Figure 1 shows that it begins at the area marked Materials. Thence, all stores proceed to the area marked Shops, which includes carpenter, plaster, paint and other construction shops. Adjoining the shops is the Assembly Bay, with the Scene Dock on one side and the Waiting Bay on the other. The Scene Dock is not shown on the chart; it may be situated either on one side of the Assembly Bay or in its rear. In the Assembly Bay, the sets are mounted on set floats, or mobile rostrums, as they are called in England. If a set is too large for one float, the rostrums may be interlocked. Minor finishing jobs are done in the Assembly Bay; thereafter, the Property Department takes over and dresses the set.

The set floats then are towed into the Waiting Bay which is divided from the stage by acoustically insulated sliding doors. The Waiting Bay must be large

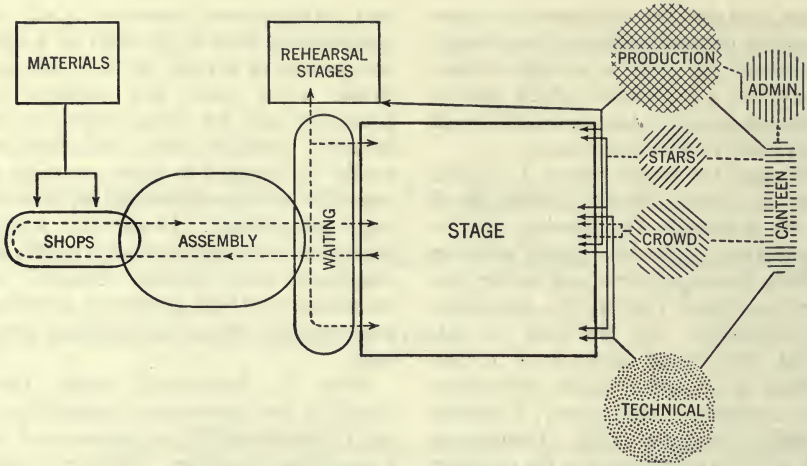


Fig. 1. The Independent-Frame assembly line.

enough to accommodate the live sets going on stage and the dead sets coming off.

In order to dress the stage with minimum confusion, the majority of sets are flown into position by the aid of an overhead gantry. This gantry consists of five banks of running bridges, each a 24-ft section, each section operating independently and capable of carrying a point load of three tons. The special rehearsal stage is off on one side, out of the way. On the front of the Stage, individual approaches have been marked out for Stars, for bit players and supernumeraries, and for technicians and production staff, in order that each element in the production group will interfere as little as possible with each other. The dressing rooms and administrative offices are behind the area marked Canteen.

The involved and radical lighting setup employed in Independent Frame has been described elsewhere.[1] Suffice it to say, nearly all Independent-Frame lighting is indirect. An ingenious reflector system is employed which dispenses with light rails and reduces the candlepower of the normally lighted set by almost two-thirds.

Construction of Independent Frame

The construction of Independent Frame begins, as all modern industrial technique begins, with intensive planning. It is not suggested that under the normal system of motion picture production planning is not intensive. In its primary stages, Independent Frame embodies little that is new. It simply carries existing practices further than is customary in the normal production.

From six to nine months before shooting date the Independent-Frame team goes to work. It begins by blueprinting the production. After the blueprints, the next step is the prefabrication of all backgrounds.

All settings must be organized and complete to the last detail before shooting begins. The first step is a library job, carried out by one or more still photographers who go on location with precise instructions as to what is needed for background process work, for transparencies, for superimpositions and for all other setting requirements. Moving and static matte effects, foreground transparencies, miniatures and models, special photographic effects and other

Fig. 2. ***A Warning to Wantons*** **shot, with the vista in back projection. The colonnade vista, in which the girls and the nun are standing, shows in brilliant detail to great depth.**

accessories are produced and fitted into the general background scheme.

Live action may be incorporated in this synthetic background through the inclusion of film; beyond a window or a door, crowd scenes, rolling waves or other movements may be introduced. The sum of these various agencies, when coordinated beforehand, is an attempt to bring the location into the studio with the greatest possible realism and at the lowest possible cost.

In his first Independent-Frame sets, Rawnsley aimed at a minimum of construction and a maximum of special effects. His success is evident when his films are examined frame by frame. It is next to impossible to discern where authentic construction ends and where process takes over. Often there is nothing on the set except a chair or a piece of furniture; or, if an entrance is required, there may be a door in its frame. The process background film supplies the remainder of the room.

Warning to Wantons, the first of his feature films, is well worth study, as he tried his complete bag of tricks in it. It is noteworthy for the manner in which the junctions of actual settings and back projection have been disguised, for the way in which transparencies, matte processes and live action have been coordinated in the backgrounds and for the clever use — and equally clever avoidance — of shadows (Fig. 2). In a number of instances Rawnsley succeeded in having an actor reach behind a nonexistent angle for a box of cigarettes. He has had an actor climb three real steps of a staircase, and thereafter left him with his foot in the air, stepping off into the back projection. In a later picture, *Floodtide*, he saved a

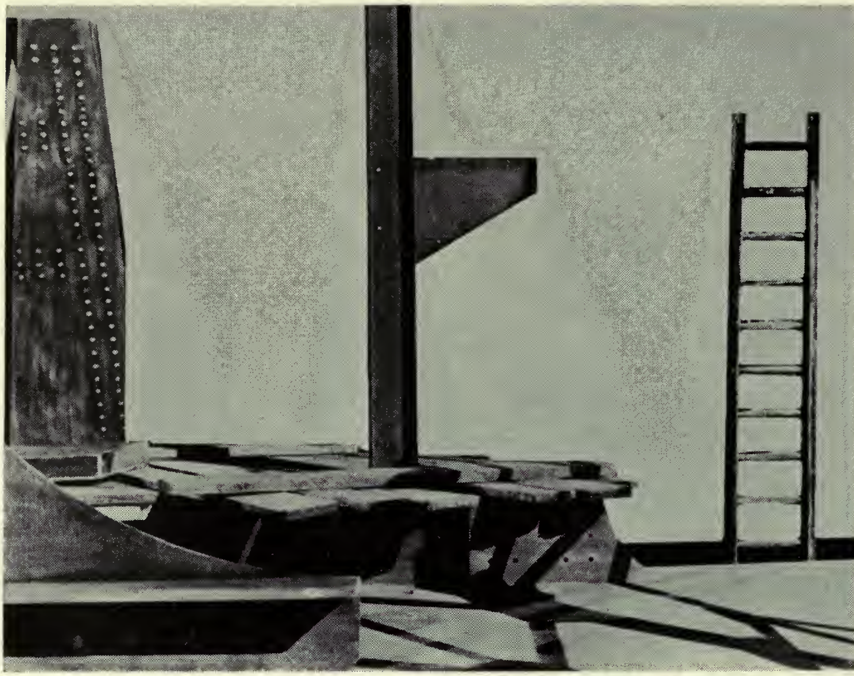


Fig. 3. The actual construction in a ship's cradle, as used in *Floodtide.*

day on location through the use of a real girder in the left foreground (Fig. 3). The remainder of the set was a back projection of a shipbuilding cradle, with superimposition of film to bring the characters across it. A quick cut, and the players stepped out from behind the girder to take up their roles.

When these prefabricated backgrounds of Independent Frame have been completed, they are recorded on a Story Reel for study, for adjustments and for a final O.K. In the same manner, sound effects and music tracks are assembled and recorded. Properties and set pieces follow into the set. Models and foreground miniatures are incorporated. The ideal — and it is quite possible of realization — is to have every stage detail settled and every set organized for rapid mounting and striking before the first rehearsal call. When the shooting begins, the stage crews, except for a minimum of technicians, have completed their tasks. The sets are final, the lighting is correct, the properties are in place and the camera angles have been decided on. The Independent-Frame production then is ready to roll. No time has been wasted nor have any costs been incurred on the shooting stage.

The Story Reel

So much for the Frame of the picture. In similar fashion the story treatment has been organized beforehand. About the same time that the Frame Team gets down to business, from six to nine months before shooting date, the Scripting Team starts to work. This team consists of the producer, the director, the writer, the set designer, the editor, the sound director and the cameraman. Their objective is to present their individual problems to each other in

order to agree on a joint conception of the production.

In British studios, under ordinary production conditions, an average of two hours in each working day is lost in floor discussions, in reconciling differences of opinion among the technicians, and in chopping and changing the script or its presentation. This does not occur under Independent Frame. When agreement has been reached, a Pre-production Story Reel is filmed. This Story Reel presents orally and visually a timed continuity of the proposed production. Sketches are prepared for every scene; complicated scenes may require several sketches. The sound track of the Story Reel consists of a narrator, who may add whatever musical score or pertinent dialogue he deems necessary to explain the plot or to make the characterizations effective. Thus, at any time before shooting begins, the entire production can be examined in sequence, can be mulled over, or can be altered without costing a minute of floor time. When it finally is approved, the Story Reel forms the basis for the compilation of the actual Shooting Script, which is prepared in the usual manner, with setting, lighting, sound, camera and action directions on one page, and the story and dialogue on the facing page.

Shooting

Now comes the call for the actors. First rehearsals are carried out by principals only. They take from three to four weeks. Thereafter there follow no more than three to five days of dress rehearsals on the process stage. At this juncture the twin stages earn their keep. A previous film may be finishing up on one half of the stage, while the dress rehearsals are conducted on the other half. This is possible only because of the prefabrication both of the Frame and of the Story of the picture, independently of each other. The majority of the technicians have done their jobs and are out of the way. Everything now is ready for the marriage of the Live Action to the prepared Frame and to the other prerecorded film material.

Thus, the shooting of the picture begins and continues under the best possible auspices, without interruptions and without changes. There are relatively few people underfoot and nothing to distract from the task in hand. As a result, the floor time, which is the biggest element in production costs, is cut substantially. More pictures can be made in a year with the existing studio facilities.

The foregoing details of the production organization of Independent Frame are, of course, little more than a summary. First in the field of results comes the all-important factor of economies.

Economies

On the first four pictures produced by Independent-Frame methods, marked savings were effected. As an illustration, the first film, *Warning to Wantons*, was allotted a budget of $600,000. Its actual cost was $360,000. The shooting time had been estimated at 14 weeks. The actual shooting time was 8 weeks.

In each of the six phases of production — the prefabrication of the Frame, the prefabrication of the Story, the Scripting of the Treatment, the Rehearsal, the shooting and the Postproduction Editing — there were noteworthy savings both in time and in money.

Such savings, in the case of a single film, are but a fraction of the economies effected if the studio can be maintained in continuous production. Then it becomes possible to stagger each of the six phases of production, so that key staffs can be employed continuously, moving on from one film to the next while the requisite producers, directors and artists succeed each other on the studio floor at short intervals. Under such conditions it becomes possible, through the many advantages of Independent Frame, to complete as many as twenty full-length features per year on a single twin-stage unit. During the shooting period, a

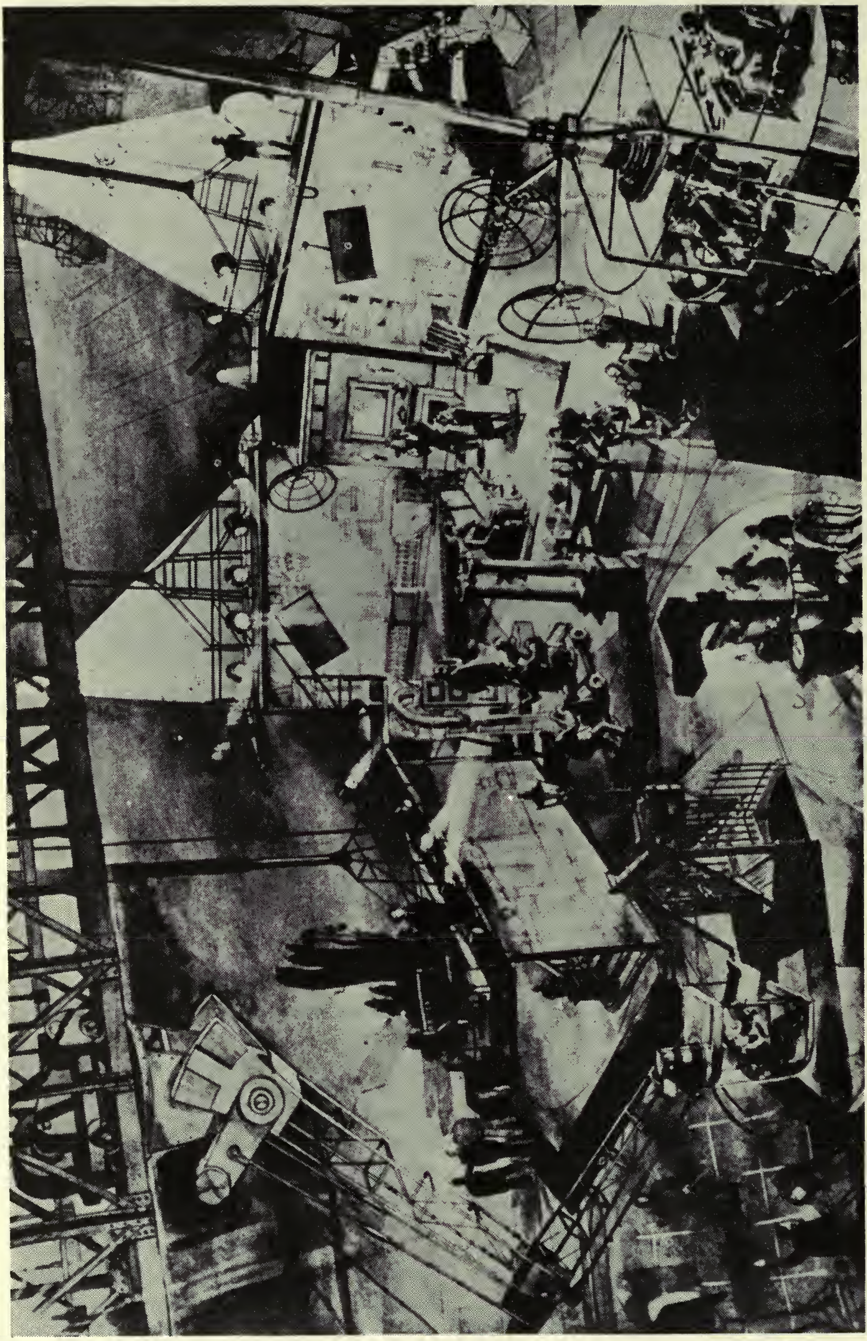


Fig. 4. The electronic stage, on which television cameras replace ordinary film cameras.

yield of ten minutes of finished picture daily is not unusual. Mr. Rawnsley, in his detailed report on the test productions, summarized the achievements of his processes in a single phrase, "Half the time at half the cost, on half the usual stage space."

In addition to immediate savings, there is a long-term economy involved in Independent Frame. Much of the prefabricated Frame is recoverable as library material. It can be combined to form new settings. It can be used for different-language versions of the same picture. The international implications of possessing settings which will allow directors in other countries to employ their own casts and to interpret scenes to suit their own audiences, may prove in time to be an important aspect of the Rawnsley technique.

The first pictures produced by Independent Frame undoubtedly fulfilled the conditions set by the J. Arthur Rank Organization. They saved money with no loss in artistic or technical values. They simplified production techniques.

Reactions

The opinions of technicians on the processes varied widely. There would have been something wrong had it been otherwise. Some denounced the processes as unreal and overmechanical. Cameramen as a whole did not like the process. They felt that their preproduction planning, in which they worked out setups and camera angles in advance, did not do them justice. In addition, they took a rather dark view of so much back projection and superimposition. But there was no evidence in the finished pictures that the camera work had suffered. The actors and actresses, who might have objected to playing against phony backgrounds, were not adversely affected and turned in their customary performances. Directional and administrative staffs were highly in favor of Independent Frame, as it halved their work and their worries. The theater audiences did not detect any differences in the settings and, after all, the customers are the final court of appeal.

Since the first four pictures, there have been several other Independent-Frame productions, most of which have played in New York and in other parts of the United States.

Television in Film Production

The original Independent-Frame technique, however, now is its least interesting aspect. David Rawnsley has moved on to more radical innovations. He always has had in mind the possibility of employing television in film production, since its use would simplify and accelerate his original aim to lower costs without sacrifice of artistic or technical quality. Here again, the Rank Organization backed him up by ordering test productions. As in the first instance, stringent conditions were laid down by which the success of such productions would be judged.

This television technique still is in process of development (Fig. 4). Briefly, six or more television cameras are substituted for standard film cameras on the studio floor. They work on a standard of definition sufficiently high to record the same quality of image as standard film cameras. They are fitted with electronic view-finders which allow the camera operator to examine the picture he is transmitting. These pictures are fed simultaneously onto electronic monitoring screens, not only in the director's control booth but also to other technicians entrusted with cutting, mixing, superimposing and combining the live action on the studio floor with previously recorded material. A combining screen allows the director to prerecord his back projection and matte processes. He thus saves considerable floor time. From a booth which may be built into the wall of the studio or may be slung from the gantry over any part of the stage, the director controls all processes. He studies the results of live action on his preview

screen, he calls for whatever changes he requires, he orders his cuts, his mixes and his superimpositions. Finally, he views the finished product on a main monitoring screen. Only then, when it has received a final O.K., does it pass to the recording room to be placed on film. Immediate processing follows and the film is fed back to the director on a scanner for a last look before he continues with the next scene. Sound is monitored in the same manner as the film images.

It would be foolish to claim that there are no difficulties in this radical process. It is only in its infancy and, like all infants, it squalls occasionally. A well-known British technician-consultant recently published the results of a sequence-by-sequence analysis of three films in order to discover the causes of additional takes and retakes, and the part that television aids and electronic monitoring play in reducing production time. His opinion is that, at the present stage of development, electronic monitoring screens are of less value than rapid "rush" developing, which allows the preceding sequence to be studied on the film within minutes of shooting. The immediate examination of "rushes" is, of course, standard Independent-Frame practice.[2]

The advantages are so great, the possibilities of electronic techniques so vast, that it would be a bold man who would say that David Rawnsley is on the wrong road. It has been stated that others in Hollywood are working toward the same end. It is fair, therefore, to assume that in the course of time Independent Frame will be something very different from what it is at present, but it will be remembered as a pioneer experiment in a new and vastly more efficient technique of motion picture production.

References

1. Kenneth Bellman, "Notes on a production technique," *J. Brit. Kinemat. Soc.*, vol. 15, pp. 143–146, Nov. 1949.
2. K. E. Harris, "Technical objectives in pre-planning production," *J. Brit. Kinemat. Soc.*, vol. 18, pp. 18–29, Jan. 1951.

Progress in Photographic Instrumentation in 1950

By KENNETH SHAFTAN

The purpose of this paper is to define the field of photographic instrumentation and to report briefly on the progress that was attained in that field during 1950.

The photographic method is used, according to Dr. C. E. K. Mees,[1] for: (1) the recording of visible images; (2) integrating radiation over long periods; (3) detecting invisible radiation; and (4) measuring the intensity of radiation.

Presented on May 2, 1951, at the Society's Convention at New York, by Kenneth Shaftan, Director, Photographic Instrumentation, J. A. Maurer, Inc., 37–01 31st St., Long Island City 1, N.Y.

Basically, both qualitative and/or quantitative data can be obtained. Relating these basic techniques to the needs of science, it may be seen that the photographic method has found exceptionally widespread use. Indeed, the photographic method is being used extensively in almost every branch of science and engineering. It is significant to note that the photographic industry of the world is three times the size it was in 1939, and that currently two-thirds of all photographic materials produced are used in business, industry, government and science.

I. HISTORICAL

Among the earliest uses of photography were the scientific. In March 1840, nine months after the French government released the daguerreotype process to the world, Dr. John W. Draper took the first successful photograph of a celestial object — the moon. At the Harvard College Observatory, attempts were begun in 1848 to make daguerreotype, or talbotype, pictures of stars,[2] with the first successful results obtained on the star Vega in July 1850. Professor S. F. B. Morse and others were active in this field at about the same time.

The antecedent techniques of motion picture photography developed by Muybridge,[3] Eakins and others were for the study of animal and human locomotion.

Moser, in 1842, first observed radioactive effects on photographic emulsions. The fogging of silver chloride and iodide emulsions by uranium salts was rather thoroughly investigated by Niepce de Saint-Victor in 1867. The researches of Becquerel, the Curies, Wilson and many others used photographic emulsions as instruments in nuclear research. Up to the invention of the Wilson cloud chamber, the emulsions used were those developed for visible spectrum photography. Today we have emulsions especially developed for nuclear studies, and, as a result, there has been a great revival in the use of nuclear photographic techniques. To date, some thirteen nuclear particles have been detected and identified through the use of these techniques.

The early efforts have been refined and extended in application, providing science with many specialties which depend in great measure on the photosensitive medium. Applications have become so widespread and diverse that, compared with the extent of the effort, relatively little has been done to coordinate this field.

II. DEFINITION

To aid in codification and unification of the field encompassing the scientific uses of photography, we need a term to describe it adequately. The term, *photographic instrumentation*, is proposed and defined as: *The use of the photosensitive medium for the detection, recording and/or measurement of scientific and engineering phenomena. Photographic instrumentation* thus includes the apparatus, the techniques, the processes and the applications in scientific endeavors.

III. THE PRIOR STATE OF THE ART

The usefulness of photographic instrumentation has been expanded slowly since its earliest applications but it has received great impetus during the last two great wars. It is not the purpose of this paper to review all that has gone before; indeed, such would be a fabulously complex and difficult task which would take many years, a large staff and considerable funds to accomplish. That this is needed is seen most clearly in the almost daily appearance of new embodiments of old, discarded and essentially worthless devices and techniques.

A number of excellent abstract and digest publications,[4–8] many of them founded over thirty years ago, have attempted to keep us abreast of doings in photographic instrumentation. But this field represents only a small part of the interest of these periodicals. It must be borne in mind that much of the information is in abstract form, requiring the reader to go to the original papers for

complete information and for evaluation of the subject matter. Also, neither the Universal Decimal Classification, nor any other classification method, is considered to have codified this field of knowledge adequately, particularly since the most comprehensive classifications have not been revised in many years.

We, here, entirely or partially exclude a number of specialized spheres of photographic instrumentation which have been given greater impetus than most others: astronomy, spectrography, aerial photography and the orthodox radiography, for example. Work in these fields has had most excellent survey and they have progressed apace as a result.

Concerning the less well established fields of photographic instrumentation, little textual information exists. One of the earliest is on the subject of spark techniques used for the study of "splashes."[9] Another early work was that of Professor Conrady and others[10] concerning a number of photographic applications in science. Photographic techniques are included in Cranz's famous *Lehrbuch der Ballistik*,[11] and in Fink's *Die Photographische Messtechnik*,[12] both of which have not been generally available in this country. Tupholme's *Photography in Engineering*[13] presents a semipopular view of some of the phases of photographic instrumentation.

Early texts on high-speed motion picture photography were written by Magnan in 1932.[14,15] Then, no text appeared on this subject until the extensive papers, first published by Fayolle and Naslin in the *1948 French Mémorial de l'Artilleria Française*, were collected into book form.[16] A short review of photography in astronomy is given in a new Kodak publication.[17]

Light sources of interest to photographic instrumentation are discussed in Bourne's work,[18] while oscilloscopic recording details are covered in a recent Ilford publication.[19] A most interesting book on nuclear applications is that by Powell and Occhialini,[20] and an excellent text by Yagoda exists on the use of nuclear emulsions.[21]

A staggering amount of material exists in the periodical and patent literature from about 1850 to the present. One can readily see that it is beyond the scope of this paper to bring to the reader the state of the photographic instrumentation art prior to 1950. There is a serious gap in the organized record of our knowledge, and it is hoped that a thorough project will one day present all the pertinent information.

Highlights of some of the more important developments of the past ten years in many photographic fields, including some of photographic instrumentation interest, are given in the new publication by American and European scientists edited by D. A. Spencer.[22] This book is necessarily brief and in summary form, but it is a most helpful review which the author hopes will become a continuing and frequent work.

Two new French works are of interest: *Chronophotographie des Champs Aerodynamiques* by Bourot,[23] covering the use of smoke particles for making aerodynamic flow visible, and *Le Cinéma Scientifique Français* by Thevenard and Tassel,[24] which is in the nature of a review of French application of motion picture photography techniques to scientific investigation and to education.

A book recently published in Germany, is noted: *Die Photogrammetrie in ihrer Anwendung auf Nichttopographischen Gebieten* by Lacmann.[25]

The High-Speed Photography Committee of this Society has inaugurated work on a treatise on photographic instrumentation by specialists in each phase of this field. This work will necessarily take some time to produce, but will fulfill a long felt need for complete and competent technical information. The Committee will no doubt present progress information as work in the field proceeds.

IV. PROGRESS IN 1950

A. Introduction

In writing this paper, it became apparent that information was to be found in an increasingly large number of scientific journals, both domestic and foreign. No single abstract or digest publication codifies the published literature in photographic instrumentation. Very often, instrumentation data are omitted from the abstract and can be unearthed only by further scrutiny. Sometimes, knowledge of the field of endeavor, or of the past work of the investigator, will lead one to information on this subject. In many cases, it was a true disappointment to find that only the briefest mention was made of the techniques employed.

In all, some 12,000 abstracts were scanned and some 500 of them were chosen for further study. Some fields have been examined only briefly and others not at all. Thus, this paper cannot be considered to be exhaustive.

An attempt has been made to read as many papers as possible and where they were not readily available, reference was made to the abstract and digest journals. In a survey of this sort, only a brief mention may be made of any one instrument or technique, and the reader is referred to the original paper listed in the bibliography for more complete information.

B. High-Speed Still and Motion Picture Photography

A number of high-speed cameras were introduced during 1950, covering a remarkable range of frame frequencies and indicating a very interesting future potential.

A modification of the gun camera used in aircraft was accomplished to provide for 1000 frame/sec for use in rocket studies.[26]

The Beckman & Whitley Temporal Sequence Camera[27] provides quantitative measurements of the velocity and acceleration of objects moving at high speeds, of the order of 2000 mph. This camera uses a slit technique, recording time sequence in a vertical plane passing through the optical axis of the lens. It is equipped with an electronically regulated power supply and timer control. Time is recorded in the form of numbers showing lapsed seconds and hundredths of a second with intermediate pips spaced at thousandths of a second. Printer dials accumulate 1000 sec/turnover and longer periods may also be handled. Event timing can also be recorded. Continuously variable film speed in either direction permits the recording of events progressing in either direction. The film used is 35-mm in 120-ft magazines. A strip is produced wherein the image is a geometric plane figure of generation with the horizontal coordinate representing time. Events taking place vertically in the slit plane are expanded horizontally, coordinated with the calibrated time scale. Gaseous-discharge light sources may be used in conjunction with this camera to produce conventional sequence photographs. The camera may also be used to record phenomena such as cathode-ray oscilloscope traces, acting as a continuously moving film camera.

A group at the Department of Aeronautical Engineering of the University of Minnesota, in a paper[28] before this Society, discussed the British Marley High-Speed Camera which provides for 58 pictures at rates up to 96,000 frame/sec. This camera had been described previously in British and French journals. It is a relatively simple device operating on the principle of a vernier and has only two moving elements: a slit disk and a capping shutter which consists of a similarly slotted disk, Figs. 1 and 2. The film is approximately 2 m long, 35 mm in size, daylight loaded and held stationary during photographing. In order that the photographs may be studied by projection, it is necessary to rephotograph each of the frames onto motion picture film. The frames produced in the Marley camera follow a complex se-

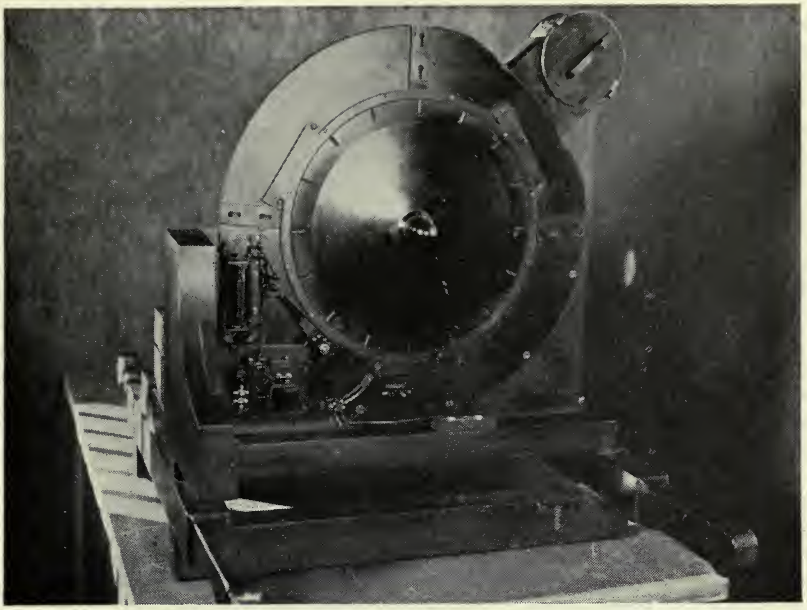


Fig. 1. The Marley Very High-Speed Motion Picture Camera (front view). (Courtesy of Hinz, Main, & Muhl.[28])

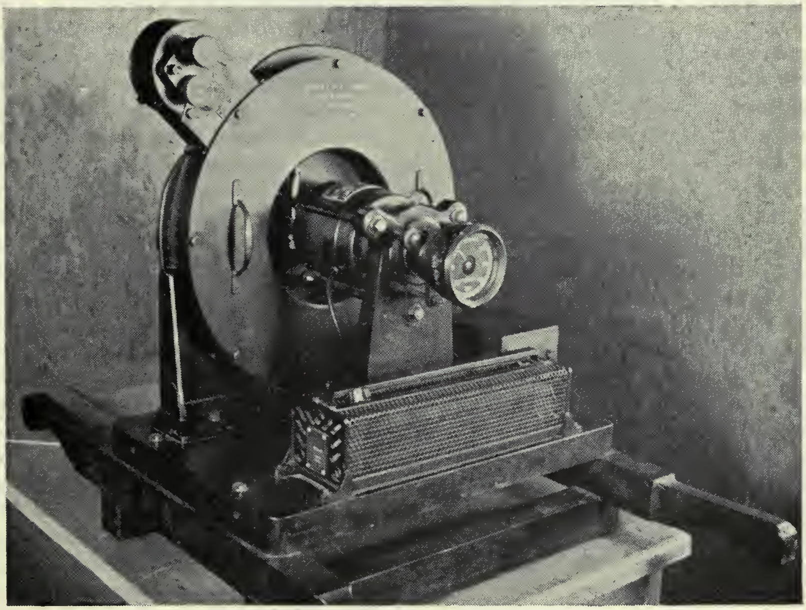


Fig. 2. The Marley Very High-Speed Motion Picture Camera (rear view). (Courtesy of Hinz, Main, & Muhl.[28])

quence, with frame No. 2 produced 48 frames following frame No. 1. Frame No. 3, again being displaced 48 numbers, is in position 38, and so on. The maximum frame frequency, with the rotor disk turning at 6000 rpm, is 96,000; the exposure duration per frame is approximately 10.5 μsec with the overall exposure time for 59 frames at 618 μsec. Gaseous-discharge tubes (FT403 and FT503) were used at various energy levels as illuminants.

A rather ingenious hand-held, high-speed motion picture camera, the Rotax,[29] uses the optical compensation of a rotating prism for image formation. This camera was designed by Askania Werke in Germany before World War II, and an early model, picked up as an aftermath of war, has been tested in this country. The Rotax employs an octahedron prism fixed axially on the same shaft as the focal plane sprocket. As the prism rotates, the image is transmitted to the film by means of a multiple fixed-prism system. The inherent synchronization of the rotating compensator and film movement produced by this arrangement and the relatively small angle of incidence through which the prism rotates per frame produce an image of fair resolution. The camera weighs 13 lb, is approximately $11 \times 8\frac{1}{2} \times 11$ in., has a continuously variable speed from 24 to 600 frame/sec, and carries 100 ft of 35-mm film. Lenses of various focal lengths may be used by means of an adapter. The motor speed may be controlled by varying the voltage applied.

Reporting before this Society, Dr. Paul Fye[30] of the Naval Ordnance Laboratory disclosed the design of the Jacobs and Klebba* high-speed motion picture camera. This camera follows essentially the principle of the Bowen and the Miller 50,000 frame/sec cameras. An image of the subject is focused onto a rotating mirror having its axis of rotation on the focal axis of the taking lens. The rotating mirror, having its plane of reflection 45° to its rotational axis, reflects the image successively through 100 framing lenses to stationary film mounted on the inside of a drum. The mirror may be revolved to speeds of 18,000 rpm, producing at this speed 100 frames at a frequency of 30,000 frame/sec. A capping shutter is employed to prevent multiple exposures. This paper also gives a short exposition of the event synchronization techniques and results of Fastax and Eastman high-speed motion picture camera photography using flashbulbs as light sources in the study of underwater explosion phenomena.

Another multiple-lens camera, but one operating on a different principle from the preceding device, has been described by L. Bull[31] of the Institut Marey of Paris. This camera produces 50 circular images of 16-mm diameter on a plate measuring 13×18 cm. Bull uses 50 lenses of 25-mm focal length, *f*/3.5, arranged in 7 staggered arcs of concentric circles, forming a close group. A shutter, in the form of a large-diameter disk fitted with slots, successively uncovers the various objectives. With the shutter rotating 60 rps, a frame frequency of 3,000/sec is produced. Because of parallax caused by the distance between the extreme lenses (of the order of 2 ft at an object distance of 3 to 4 m, where it becomes negligible), the camera cannot be used for cinemicrography or for the photography of very close objects. The camera may be used to project the images produced in their normal order by mounting a projection source thereon.

A multiple-slit focal plane scanning shutter, used in conjunction with a rotating mirror, forms the basis of an ultra-high-speed motion picture camera developed by M. Sultanoff[32] of the Ballistics Research Laboratory, Aberdeen, Md., following the work of F. E. Tuttle.[32] The object to be photographed is imaged by a lens of long focal length onto a grid

* S. J. Jacobs, Naval Ordnance Laboratory, and A. A. Klebba, Woods Hole Oceanographic Institution.

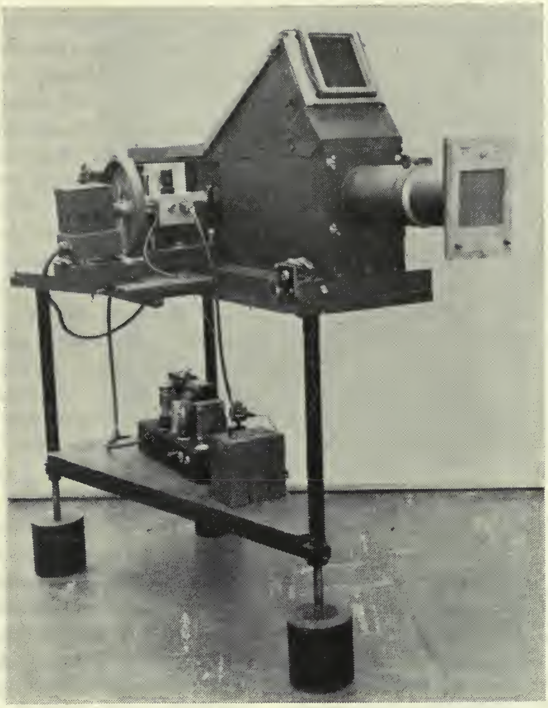


Fig. 3. Sultanoff-Ballistics Research Laboratory Ultra-High-Speed Motion Picture Camera. (Courtesy of M. Sultanoff.[32])

(two types are described, 0.0005- and 0.0001-in. slits cut on opaque coated glass 4 in. $\times$ 4 in. $\times$ $\frac{1}{8}$ in.). A second imaging lens of 360-mm focal length focuses the image onto a rotating mirror which in turn reflects the image, using a 20-in. optical arm, onto a 4 $\times$ 5 in. photographic plate. Thus, a series of individual slit-width images of a fixed-space varying-time nature are produced. By moving the taking grid across the developed plate, a slit width at a time, successive frames are uncovered and may be viewed and measured. Using a grid with slit width of 0.0005 in. and a rotational mirror speed of 500 rps (with the 20-in. optical arm which produces a maximum image speed of 0.122 in./μsec), 2.5 $\times$ 10^8 frame/sec are produced; and with a 0.0001-in. slit-width grid, 1.25 $\times$ 10^9 frame/sec. At 10^8 frame/sec, the total exposure time for 30 frames is 3 $\times$ 10^{-7} sec. The camera described by Sultanoff is shown in Fig. 3, and is a modified Bowen RC3 Rotating Mirror Camera. A further redesign is in progress.

A device permitting exposures as low as 1-μsec duration at intervals of 2 μsec (500,000 frame/sec) was disclosed by Bartels and Eiselt in the German journal, *Optik.*[33] In this camera system, the image is focused upon a small mirror rotating at high speed and thence upon a series of stationary mirrors, from which it is focused upon stationary film.

During 1950, there was disclosed[34] the Zarem-Marshall Multiple Kerr Cell

Camera built at the Naval Ordnance Test Station, Pasadena, Calif. This camera is a further extension of the authors' work in electronic pulsing of a nitrobenzene Kerr Cell. An arrangement of three small Kerr Cells (which are pulsed in succession), imaging lenses and mirrors produces three images on a Speed Graphic Camera plate. The effective aperture of this system corresponds to $f/16$ and it has a total angular field of about 5°. The exposure duration may be varied, with effective exposure durations of 0.007 to 7 μsec stated to have been achieved. The interval between exposures can be made, it is said, as small as 0.01 μsec, equivalent to a frame frequency of 100,000,000/sec. An example of three exposures of the vaporization of a fine gold wire is shown with an effective exposure time of 0.04 μsec, and a frame frequency of 4×10^7 frame/sec. Pulsing circuitry and characteristics of the Kerr Cell and the nitrobenzene used therein are given.

Another Kerr Cell photographic instrumentation for ballistic photography was described by Quinn, McKay and Bourque[35] of the Canadian Armament Research and Development Establishment. In the study of ballistic phenomena, it was found necessary to photograph projectiles under conditions where the subject is either wholly or partially surrounded by a glowing medium of considerable luminosity such as a projectile striking armor plate or a projectile emerging from a gun muzzle. A system for synchronizing a gaseous-discharge tube and a Kerr Cell was devised to study these phenomena. The Kerr Cell provides for an effective exposure duration of the order of 2 μsec and operates at a peak voltage of 36 kv following previous German work. Super XX film and a flash tube, FT125, operating at 18 kv are used. Circuitry and results in ballistic studies are given in the report and a photograph of a 37-mm projectile taken shortly after penetration of a metal target plate is shown in Fig. 4.

A comprehensive study of a Kerr Cell for photographic purposes was made in England by Holtham and Prime.[36] The exposure time used was 2 μsec and provision was made for a variable time delay up to 0.1 msec. An aerial camera using an Ektar 18-cm $f/2.5$ lens, was modified to receive the Kerr Cell and 35-mm film. Image formation and photometric analysis were studied, and it was noted that the reciprocity curves of the emulsion show that the density obtained is not equal to that which would be obtained using the same illumination from a constant source. The transmission found through the system was of the order of 5% (50% for the Kerr Cell; 32% for each of the polaroid J films). Parasitic illumination, affecting the spectral quality of the light transmitted during application of voltage, was reduced by the use of an appropriate color filter. A rotating mirror and constant light source were used to illuminate the subject, the mirror being synchronized to the Kerr Cell opening. This Kerr Cell system has been employed in the measurement of spark channel characteristics, such as growth of the spark channel, its diameter and radial intensity variation across the spark.

The Kerr Cell has now evolved from a shutter for single-frame and three-frame high-speed still photography into a device for high-speed motion picture photography as described by Bowersox[37] of the Jet Propulsion Laboratory, California Institute of Technology. In order to increase the effective window area, a combination of three or more electrodes and a separation of sections of a single Kerr Cell has been used. At California Institute of Technology, a cell is being used with four separate sections, each section having three electrodes. An embodiment is described consisting of four Kerr Cell shutters mounted in a vertical line immediately in front of four lenses, in turn fixed close to the film held on a drum of 15-in. diam. The camera is shown in Fig. 5. The Kerr Cell

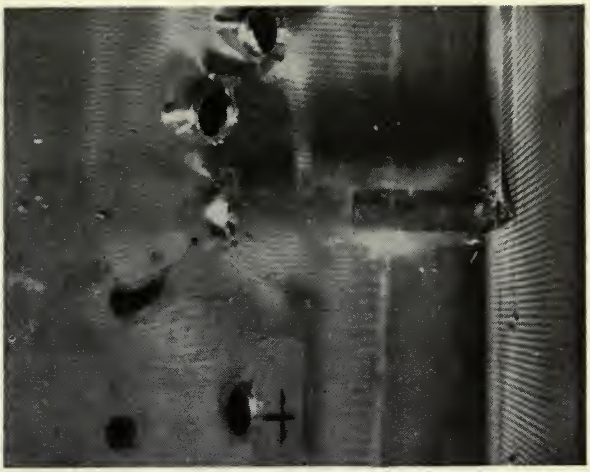


Fig. 4. Kerr Cell photography of a 37-mm projectile taken a short time after penetration of a metal target plate. (Courtesy of Messrs. Quinn, McKay and Bourque,[35] Canadian Armament Research and Development Establishment, Valcartier, Quebec, Canada.)

shutters are operated in sequence from top to bottom producing successive frames across the width of the film. Thus 620 frames, 0.3 in. square (roughly the same as 16-mm size) at a maximum speed of 50,000 frame/sec, are produced on a 4-ft long strip of 70-mm film. The cells are pulsed for only one drum rotation. Variable exposure durations are available of 1, 2, 3, 5, 6 and 10 μsec. The Kerr cells are operated on 12-kv pulses; the effective aperture for the system is *f*/5. The resolving power is said to be limited chiefly by the film motion (i.e., exposure duration), and secondarily, by the type of film used. A standard resolution chart mounted on a disk rotating at 10,000 rpm was photographed by this camera and shows a resolution of 14 lines/mm. At a frame frequency of 40,000/sec with an exposure duration of 1 μsec, the resolution is approximately 20 lines/mm.

A brief German paper[38] reviews some of the early work of high-speed photography including the work of Cranz who, in 1909, made a series of exposures at 5000 and, in 1912, at 100,000 frame/sec. A Kerr Cell producing exposure durations as short as 10^{-8} sec is described.

The development of the iconoscope

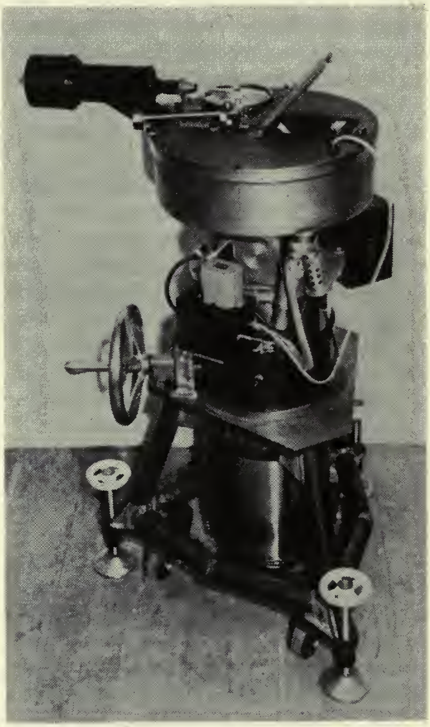


Fig. 5. Bowersox-California Institute of Technology (Jet Propulsion Laboratory) Very High-Speed Kerr Cell Motion Picture Camera. (Courtesy R. B. Bowersox.[37])

and the image orthicon (image converter tubes) as electrooptic shutters for very short exposure durations, holds a great potential for the future. Some of the initial work was carried out in England by Prime and Turnock,[39] Courtney-Pratt[40] and by others, and is also the subject of a paper to be given at this series of meetings by A. W. Hogan[299] of the Naval Ordnance Laboratory.

The use of the iconoscope as an electrooptical shutter depends on the storage characteristics of the mosaic. The electron image formed thereon by a transient phenomenon may be stored for a period of time before being scanned off by the electron beam of the iconoscope. A very short exposure period permits image formation and storage. The image thus stored is subsequently reproduced on a display tube by scanning the mosaic only once after completion of the phenomenon. The display tube may then be photographed producing, in effect, a high-speed still photograph. Nonluminous objects must be strongly illuminated. Using a medium-fast emulsion, a very satisfactory image of a disk rotating at 6000 rpm was obtained[39] during a 25-μsec exposure duration with the lens aperture open to $f/11$, and with an illumination of approximately 550 μsec duration. Using a faster emulsion, a larger lens aperture and an electronic light source of the same power but of shorter duration, exposures of 0.1-μsec duration have been readily achieved.

The inconoscope produces a secondary emission forming a ghost image and has tended to be replaced by an image orthicon which does not produce such secondary emission. However, with the image orthicon, a slight image diffusion results because of electron charges spreading onto adjacent mosaic elements. Spark phenomena have been studied by this technique. This system has certain advantages over the nitrobenzene Kerr Cell, and would seem to point the way to a most interesting future. (See also p. 458.)

Although high-speed still and motion picture photography have been applied in many studies, only a relatively few have found their way into the journals. Some of these are noted below.

In ballistics studies, a combination of streak photography and microsecond flash techniques accomplished simultaneously has been disclosed.[41] A 35-mm General Radio Continuous Film Camera was used to record self-luminous phenomena associated with the flight of particles produced by shaped charges: the velocity of the particles, variations in particle luminosity during flight, and the duration of burning of the eroded material. The smoke trail spatial distribution and its change with time, essentially nonluminous phenomena, are illuminated by means of microsecond flashes at a rate of 1000 flashes/sec. Similar techniques have been used in the past in connection with the simultaneous streak and image photography of gas-bubble phenomena in underwater explosion studies. In studies of this nature, the phenomena are not reproducible from shot to shot, and, hence, the data could not have been obtained by using these two techniques individually or in succession.

The released photographs of the first atomic explosion in New Mexico[42] were measured to determine the radius of the ball of fire for a large range of values of time measured from the start of the explosion. Energy in terms of equivalents of TNT was calculated, and two estimates of 16,800 tons and 23,700 tons were arrived at. The photographs were used also to measure the velocity of the rise of the glowing center of the heated volume of gas left behind and was found to be 35 m/sec. Other quantitative characteristics were determined.

High-speed still and motion picture photographic studies applied to the study of the airborne characteristics of underwater missiles were reported by Christie[43] of the Naval Ordnance Test Station, Morris Dam, Calif. In order to determine a torpedo's air velocity during free

flight prior to water entry, a multiple-image-recording "flare camera" is described. Several models of this camera have been produced, the latest employing a plane parallel glass plate rotating at 30,000 rpm, and producing multiple images in the form of a series of dots on a single photographic plate of two pyrotechnic flares attached to the tail of the test torpedo. Space-time information is reduced and velocities calculated.

The application of high-speed (short-exposure) photography to the rocket test program using Bowen-Knapp cameras with color film, was discussed by Elmer[44] in a paper delivered before this Society.

In the study of flame phenomena, a group at New York University[45] utilized high-speed schlieren motion picture photography.

High-speed motion pictures at frequencies up to 10,000 frame/sec were used[46] to study the process of deformation and rupture in tensile specimens of aluminum and brass at high strain rates. Most of the specimens broke too rapidly to be recorded by the camera, the break taking place in less than 10^{-4} sec. This break occurred in regular fashion along a line inclined at approximately 60° to the axis of the specimen.

The development of long a-c arcs, at currents of 46 to 6000 amp and lasting for 0.56 to 1.12 sec, was studied[47] by means of still and motion picture photography and by high-speed cinematography of the order of 1000 frame/sec. The deionization time of the arc was determined.

A Kerr Cell apparatus was set up to provide a series of superimposed photographs[48] in the study of the cathode spot of transient arcs using the liquid sodium–potassium alloy as the cathode. Quantitative behavior of this cathode spot with regard to current and under the influence of a magnetic field was studied. The interval between each exposure was varied and the number of exposures adjusted in order to show a complete picture of this phenomenon. The Kerr Cell was placed just outside a low-power microscope eyepiece.

The effect of arc-current gas pressure, kind of gas, and magnetic field on the motion of the cathode spot in a direction opposite to that predicted by Ampere's Law has been studied at the General Electric Research Laboratory.[49] High-speed motion pictures at 4000 frame/sec were employed to observe and measure the velocity of this phenomenon.

High-speed still photographs were used at the Hydrodynamics Laboratory of California Institute of Technology[50] to study regular and Mach intersection in hydrodynamic jumps. Hydrodynamic jumps were produced by two wave generators in a water table approximately 5 ft $\times$ 4 ft $\times$ 2 in. deep. The bottom of the tank was made of glass with a grid of known dimensions. A spark source was used below the glass bottom, producing a refraction pattern on photographic paper placed above the water surface. The resultant photographs are similar to the schlieren presentations of gas flows and permit measurement of associated phenomena.

High-speed still photographs taken of small spheres entering water vertically at various velocities were used[51] in the study of the virtual mass of such spheres. High-speed motion pictures were also employed to permit determination of space-time data for a series of spheres of various sizes and at various entry velocities. From the resultant acceleration data the virtual mass was calculated.

High-speed motion picture photography was also used quantitatively at 1500 frame/sec to determine the velocity of flow of blood in the basilar artery of the rabbit during the cardiac cycle.[52] The blood stream was made recognizable by the injection of a 0.05% fluorescein solution with emulsified olive oil.

High-speed motion pictures were used in textile research for the determination of the impact of raindrops on fabrics.[53] A Zeiss Ikon high-speed motion picture camera operated at frame frequencies to

6000 frame/sec was employed to determine the pressure–time relationship under such action. The velocity of the drops at the time of impact was measured from the film which was used to record two successive drops per roll. It was found that during impact, the upper parts of the drops retain their spherical shape while the lower parts are pressed outward as a continuous film. The upper part has about the same velocity as that of the drop immediately before impact. Some time thereafter, the drop breaks down into small particles and the second drop following on wet fabric was found to lose its spherical shape more quickly. The center of gravity of the deformed drop was determined and from this the pressure was calculated.

Applications of high-speed motion picture photography in textile processing research were disclosed by Fisher and Burnett.[54] The action of a shuttle in a production loom was studied as were the heddle action on an experimental loom, the traveler on a spinning frame, and yarn and cord breaks under laboratory conditions and during spinning of cotton yarn. It was noted that the traveler on a spinning frame would require frame frequencies greater than 5000/sec.

Other applications of high-speed motion picture photography included ironmaking,[55] paper-mill maintenance,[56] and the analysis of vacuum cleaner mechanical components.[57]

C. Standard Still and Motion Picture Photography

The more orthodox still and motion picture photographic instruments and techniques have been adapted in several interesting ways for scientific studies.

A Kodak 35-mm still camera was adapted by Jean St. Thomas of the Civil Aeronautics Administration as a photographic transit for aircraft approach-zone studies.[58] A thin glass grid was placed in front of the focal plane; various grid lines represented horizon, glide-angle ratios, and the edges of the approach zone. Two camera stations were used and obstructions in the approach zone rapidly located and measured. A pinhole camera equipped with a focal-plane grid and mounted in the pilot's seat was also designed to permit direct-angle measurements of cockpit visibility characteristics.

A Cine Special operated at frame frequencies from 8 to 32/sec was used to record electron-microscope images.[59] The authors state that this is the first time motion pictures of electron-microscope images have been made. Motion picture studies of electron bombardment of various types have been made in conjunction with the development of electron microscopy by such workers as von Ardenne, Ruska, and others in Germany long before World War II. This technique has been used, according to the current paper, in the study of some of the effects of electron bombardment on colloidal crystals.[60] The viewing screen of the electron microscope is adjusted with its plane normal to the optical axis of the camera. The Cine Special is fitted with a 4-in., *f*/2.7 telephoto lens. A field of view of 30° is stated to be achieved. Super XX Negative film was found to produce the best contrast. At frame frequencies above 32/sec, the contrast was said to deteriorate. Resolution of 150 to 300 A is achieved. Some instrument adaptation is necessary to provide adequate illumination, and X-radiation must be guarded against. Solid–liquid–solid changes by recording Bragg reflections were investigated. A preliminary effect of electrons upon crystals is to drive off water. In salt crystals, a residual envelope is left in which small particles, both solid and liquid, are observed to move rapidly due, it is believed, to Brownian movement and convection. Tungsten oxide crystals and carbon black were also studied under an electron bombardment.

An application of multiple still photography in the study of size and charge of microscopic particles was described by

Kunkel and Hansen.[61] Horizontal electrical deflection of particles settling under gravity are recorded photographically. The rate of fall is measured and the Stokes' Law diameter calculated. It is also possible to calculate the approximate charge of the particles from the simultaneous electrical deflection. A strong dark field illumination is provided by an A-H6 high-pressure mercury-arc source with a baffle cutting out the central cone of the highly divergent light beam. Only light scattered into this dark cone is recorded on the film. A rotating disk, carrying four 6° openings (two or three of which may be closed according to the time intervals to be observed), is driven at 450 rpm. The intensity of the arc source fluctuates with 120 maxima/sec requiring alignment of the shutter disk in such fashion that maxima occur whenever an opening crosses the optical axis. A capping shutter for the camera is provided. A copper chloride solution is used to cut out about 95% of the infrared radiation of the source. Powder specimens are allowed to settle through a 3-ft settling column and enter a small analyzing chamber perpendicular to the optical axis of the lens and light source. To reduce heating effects, at most 30 flashes of 1/450 sec each, for a total exposure of 1 sec, are employed. Quartz crystals of sizes from less than 0.5 μ to 30 μ in various electrical fields were studied and trajectories measured.[62] In addition, charge distribution in coarse aerosols as a function of time were studied.[63]

Still photography has been applied to high-altitude rocket studies[64] to determine missile orientation, to make meteorological studies, and to investigate the possibilities of photographic reconnaissance from guided missiles. A K-25 aerial camera was modified to provide for greater acceleration than normally encountered in aerial photography and for insulation against low temperatures. Super XX and Kodacolor films were employed, with Kodacolor producing a deteriorated color image. Gun cameras using Kodachrome and Super X did not fare too well. A photographic method for the measurement of high-altitude orientation of rockets was developed.[65]

Orthodox photography has been applied to the determination of burning velocities of fast-burning mixtures.[66] Photographs obtained show two uniform flame speeds or speeds which vary from one uniform value to another due to changes in the orientation of the flame front. The photographs point out that the uniform motion may be compounded from these two speeds in any proportion and, therefore, suggest that electrical methods for determining flame speeds yield results which are not necessarily reliable.

Motion picture photography was used to study the convection currents near a carbon arc through photography of carbon particles moving in a dark field near the arc column.[67] From these results and a knowledge of the spatial temperature variations, the convective heat loss from the arc channel may be found and compared with the electrical energy input.

Time and motion study techniques employing motion picture photography continue to produce useful results in such matters as method analysis,[68] the setting of performance levels,[69] and training of personnel to better utilization and reduced time and effort.[70]

D. Cathode-Ray Still Oscillography

Several still cameras designed for oscilloscope trace recording were announced during 1950. Moving-film-type recorders are not discussed in this section, but under *E*, below.

DuMont has brought out three still cameras for oscillographic recording. Type 297 consists of an oscilloscope hood carrying an *f*/2.8 75-mm lens, a variable-speed shutter, and a Polaroid-Land Camera back. The writing speed is said to be to 1 in./μsec for the *f*/2.8 lens, and to 2 in./μsec for an *f*/1.9 lens which

may be procured separately. An illuminated data card may be recorded on the film. The DuMont Type 296 still camera for oscillographic recording consists of a Bolsey-type camera, an $f/2.8$, 41.5-mm lens, and is said to provide a writing speed of more than 10 in./μsec with a Type 5RP-A cathode-ray tube operated at 12,000 v. A variable-speed shutter and a means for simultaneous viewing is provided. The third camera DuMont offers is their Type 295 fitted with an $f/1.5$, 50-mm lens. Thirty-five millimeter perforated or unperforated film or paper of 36-exposure length in the standard cassette may be used. A light-tight take-up cassette with a built-in cutting knife is provided for short-run operation. It is said that writing speeds greater than 35 in./μsec are possible with the Type 5RP-A cathode-ray tube again operated at 12,000 v. DuMont states that the $f/1.5$ lens will permit the recording of traces at writing speeds as high as 80 in./μsec and that an $f/1.0$, 2-in. lens is also available. The shutter may be operated manually or by a solenoid, and provides time and bulb exposures. A data card may be recorded on the film.

The Fairchild Camera and Instrument Corporation has also brought out a Polaroid-Land Oscilloscope Camera[71] fitted with an $f/2.8$, 75-mm lens, a variable-speed shutter, and provision for two images per $3\frac{1}{4}$-in. $\times$ $4\frac{1}{4}$-in. frame, or a total of 16 exposures per roll of film. At 3000 v, writing speeds to 1 in./μsec may be recorded.

A number of papers were presented concerning the elements of cathode-ray oscillographic recording.[72–75] Calibration lines and a data card are recorded on the same film as the cathode-ray-tube-image by a newly devised system.[73] Notations are marked on a paper mask surrounding the cathode-ray screen. Fine wires are used to construct a calibrating grid and both are illuminated by a light source between the camera and the cathode-ray oscillograph.

Fraser and Badgley of the Naval Photographic Center[76] have recorded color television images at 24 frame/sec. A 16-mm Mitchell Motion Picture Camera was fitted with a Polaroid $f/0.7$ lens for recording color television broadcasts at 24 frame/sec using a 177° shutter. A Berndt-Maurer 16-mm Camera with a fixed 180° shutter and an $f/1.4$ lens was used to record both color and black-and-white telecasts. CBS, RCA, and CTI color television presentations have been recorded with various camera and lens combinations.

Cathode-ray still photography has been applied to the measurement of vertical and horizontal growth and propagation of a thunderstorm from sequence photographs of the PPI and RHI presentations of such a storm in its initial precipitation stages.[77] Rapid vertical growth after a first precipitation was detected and uniform horizontal growth observed.

E. Continuously Moving Film and Image Systems

A photographic method used in England for the recording of displacement versus time phenomena was described.[78] Small spherical reflectors are attached to, or formed upon, the surface of a moving body, producing point images of a fixed light source. Thus, the point source-image moves with the body under study and by recording its motion with a continuously moving film or rotating drum camera, a time-displacement record is obtained. The record takes the form of a fine, sharply focused, continuous line from which space-displacement measurements can be made. It is possible to carry out such photography under normal lighting conditions. The camera described in this paper gives time scales in the range of 0 to 315 in./sec. This technique has been applied quite extensively in this country to shock, vibration and explosives studies.

In connection with shock and vibration studies, Vigness and Nowak,[79] of the Naval Research Laboratory have de-

scribed a modification of the standard streak-photography technique. Small reflectors such as ball bearings have been used in orthodox streak photography in a manner similar to that described above. However, a source of error in the standard streak-photographic method lies in the possible motion of the object in a direction parallel to film motion. The modified streak method of Vigness and Nowak was devised to eliminate this error, to permit measurement of large displacements and to obtain an accuracy within a few thousandths of an inch. The object photographed consists of a series of white lines an equal distance apart, marked on a dark background. These lines are in a plane perpendicular to the direction of film motion. The direction of motion of this object, rigidly attached to the part under study, should be perpendicular to the camera optical axis and to the direction of film motion. The camera lens will focus an image of these lines on the film. A cylindrical lens, on the plane surface of which is a slit parallel to the direction of object motion, is placed just before the moving film and perpendicular to its direction of motion in order to focus these lines to approximate points. Motions of the objects in a direction parallel to the film motion will not result in any displacement of the image on the film. Small rotations in a plane perpendicular to the camera's optical axis will produce second-order errors, and motions out of this plane will result in the usual scale changes in depth-of-focus problems. This technique has been used to study displacement of many inches measured to an accuracy of a few thousandths of an inch, and to 10 μsec.

DuMont announced a continuously moving film camera, their Type 321, which is characterized by a 400-ft capacity of 35-mm film or paper, and a range of linear film speeds from 0.82 in./min to 15 ft/sec, in 18 fixed increments.

The Lydiate Ash Laboratories in England exhibited their Type 200 continuously moving film camera. This camera, representing a thorough and fundamental design approach, provides, through a gear box having a 60 : 1 change of speed (which can be obtained with the camera in operation), film speeds from 3 in./min to 120 in./sec. Full electronic motor control is employed. Other features are a 400-ft, 35-mm film capacity in interchangeable magazines; a built-in timing marker; provision for photographic data cards; and push-button operation through interlocking relays. A higher-speed version, providing to 40 ft/sec, has also been exhibited.

An interesting French camera, a high-efficiency streak camera, was described by Malan[80] for studying the correlation between the optical and electrical effects of lightning strokes. The camera produced combines advantages of other previous devices such as drum recording and ease of film changing. The film remains stationary, while the optical system is mounted in a rotating drum. Beside a reflecting prism and an objective, a Wollaston prism mounted between these is given an epicyclic rotation at half the speed of rotation of the drum. This counteracts the rotation of the image around the reflected optical axis. A few modifications make this apparatus suitable for the recording of oscillograms of transient phenomena. The apparatus carries 100-ft of 35-mm film, permitting 23 successive exposures. The only adjustment necessary between exposures is the rotation of a handle which winds the film to the next unexposed position. The objective is a 50-mm, $f/2.8$ lens, and rotation of the optical system is carried out at a speed of 510 rpm. The film exposed during photography, upon the opening of an electromagnetic shutter, is 112 cm long, and the linear speed of the image is 952 cm/sec.

A technique for time and motion study was described, in an English journal,[81] in which time-displacement information is recorded on a single plate. In certain time and motion study work, it is possible

to employ small light sources affixed to the object under study, such as the hands of an operator. In subdued light, the operator goes through his prescribed motions using an orthodox still camera with the shutter open. A pair of traces formed by the light sources is thus recorded on the film. In the technique disclosed, essentially a modification of a system employed by Gilbreth many years ago, the lights attached to the worker's wrists are pulsed at a known time interval permitting the reduction of space-time information.

The mechanism of detonation has been studied by Pike[82] through the use of high-speed mirror cameras having writing speeds of from 1 mm/μsec to over 4 mm/μsec. By electronic means, writing speeds of 24 mm/μsec have been achieved. Similar work was reported by Johansson[83] who used a rotating-mirror camera having a writing speed of 0.9 mm/μsec for measuring the velocity of the air-shock wave from the flat end of a cylindrical stick of explosive. The detonation velocity for the explosive (60% PETN and 40% TNT) was found to be 7400 m/sec. As the air pressure decreases, the shock wave velocity increases; at 2 cm from the explosive face at normal atmospheric pressure this velocity was 6500 m/sec, while at 0.5 mm of mercury it rises to 17,500 m/sec.

A series of rotating mirror cameras used as streak cameras for the study of explosive phenomena was reported also by Evans,[84] Davies, Owen, Edwards and Thomas,[85] and Adams,[86] reporting, respectively, on cameras having writing speeds up to 1 mm/μsec, 4 mm/μsec, and 4 and 6.5 mm/μsec. The latter two cameras are of particular interest. In the 4-mm/μsec camera, provision is made for the simultaneous observation of a vertical and a horizontal slit; the image of each slit is traversed along an independent quadrant (track radius, approximately 19 in.) by means of a $2\frac{1}{2}$-in. square section mirror, rotating at 40,000 rpm. By means of interchangeable objectives, distances from 20 ft to infinity can be covered. The film width is 90 mm, of which 2.75 in. is available for recording. The output from a magnetic pickup on the mirror shaft is fed to a tachometer circuit which measures the speed of rotation of the mirror. The same circuit is used to provide the firing impulse which initiates the charge, thus insuring that the record appears on a predetermined position of the film. In the 6.5-mm/μsec camera, a laminar rotating mirror, $1\frac{1}{2}$ in. $\times$ 1 in. $\times$ 0.1 in., is driven by compressed air at a speed of 80,000 rpm. The mirror speed measurement and the event synchronization for this camera are similar to those for the 4-mm/μsec camera, but an additional time device is provided in the form of three spark gaps inside the camera body, triggered at known intervals during the recording period.

An additional use to which the image-converter tube has been placed was reported by Courtney-Pratt,[87] the device producing a record similar to that from a rotating-mirror camera. In this case, the cathode image is restricted to a narrow slit. By this method, writing speeds of 100 mm/μsec have been obtained with a time resolution better than 10^{-9} sec.

A continuously moving film camera, having a temporal resolution on the film of 1.5 mm/μsec was used in England by Higham and Meek[88,89] for the determination of the lengths and the rate of expansion of long gaseous spark channels during the first 10 μsec of their growth. Measurements were also made with the rotating mirror scanning an image of the spark across a photomultiplier connected to a high-speed oscillograph to provide radial light distribution across the spark channels. Sparks of various peak currents in air, N_2, O_2, and H_2 at atmospheric and reduced pressure were investigated.

Kock and Harvey,[90,91] of the Bell Telephone Laboratories, employed a Polaroid-Land Camera in a darkened room to photograph sound waves which are portrayed by a small lamp moving up and

down as the lamp progresses in successive planes across the sound field. The intensity of the light is varied automatically in accordnce with the sound level as determined by a small microphone attached to the lamp. The properties of sound-focusing systems have thus been investigated. By this method, sound-field mapping is obtained with a fixed photographic plate and a continuously moving subject.

F. Data Recording

There has been a considerable impetus in the development of data-recording cameras. Essentially based upon the requirements of aircraft design, the British Auto Camera, introduced several years ago, was the subject of a 1950 paper.[92] This camera permits the taking of 200 exposures, 1 in. square, on approximately 18 ft of 35-mm film. The camera has a spring-wound motor of a design permitting all 200 exposures to be made on one winding and an electrical release for remote control which trips the shutter and releases the spring for advancing the proper amount of film. This camera comes equipped with a 36-mm, *f*/3.5 lens of special design which covers about 35° of angular field. A variable-speed shutter permits frame frequencies up to 4/sec. The camera is $8\frac{7}{8}$ in. long by $3\frac{3}{8}$ in. wide by $3\frac{1}{2}$ in. high. It is operated on 24 v d-c, and weighs, with film cassettes, $5\frac{1}{2}$ lb. An electrical contact is incorporated which can be used to operate an exposure indicator or a discharge lamp.

A Swiss 35-mm gun camera, the Euram, was introduced in 1950.[93] This camera operates on 24 v, and provides for single-frame exposures at predetermined intervals, or motion picture frequencies at 24 frame/sec. This camera carries 112 ft of 35-mm film in a detachable magazine which is provided with an automatic loop former. The overall dimensions are approximately $5\frac{7}{8}$ in. high, $5\frac{3}{8}$ in. wide, and $16\frac{3}{4}$ in. long, and the camera weighs approximately 12.2 lb in the loaded condition. Four lenses may be used interchangeably, and the rotating shutter has a 160° aperture. The film is advanced by a positive claw movement alternating with a positioning pin.

The Automax 35-mm data-recording camera, built in this country by Guild Laboratories of Los Angeles, was announced. This camera can be operated locally or by remote control, under single-frame operation with an external intervalometer from 1 exposure/hr to 5 exposures/sec, and under motion picture operation either 12 or 16 frame/sec. Film exposure duration is the same for both interval and cine operation. This camera is fitted with a standard 400-ft Mitchell Magazine for 35-mm film, but other capacities are available. The Automax is designed for aircraft accelerations. A film-driven switch actuates an electrical footage counter, and also gives remote indication of camera operation. A variety of motors is available for various field or mobile applications. The camera without magazine measures 6 in. $\times$ 5 in. $\times$ $2\frac{1}{4}$ in., with the motor extending from 2 to 3 in. beyond the $2\frac{1}{4}$-in. dimension. The weight, with aircraft motor, loaded 400-ft magazine, and lens, is 12 lb. The camera is designed for an operating temperature range of $-40°$ to $+$ 160 F.

Another data-recording camera, the Fairchild-North American Aviation Camera, was briefly described in the "New Instruments Section" of the *Review of Scientific Instruments*.[94] This 35-mm data-recording camera, mounting interchangeable Mitchell Magazines of 400-ft or 1000-ft capacity, features remote selection of 4, 8 and 16 frame/sec, with constant exposure rate at 1/50 sec at any of these frame frequencies. In addition, single-frame operation, either manually or by intervalometer, is possible. This camera has been designed to operate at a vertical acceleration range of -2 to $+2\,g$, at a temperature range of -40 F to plus 160 F, and at altitudes up to 60,000

ft. Optional power requirements are 28 v or 110 v. Somewhat higher frame frequencies are available in a special model. The camera size is $14\frac{5}{16}$ in. long by $8\frac{3}{4}$ in. wide by $15\frac{1}{4}$ in. high. The weight of this camera, with 400-ft magazine is approximately $26\frac{1}{2}$ lb. A 25-mm lens is regularly supplied.

The Cook Research Laboratories disclosed their Model A-1 Data Recording Camera,[95] which provides for remote single-frame data-recording photography at frame frequencies up to 4/sec. This camera has a magazine carrying 200 ft of 35-mm film with a built-in Geneva-type intermittent. A 50-mm, $f/1.4$ lens is normally supplied. The shutter is completely open within 20 msec after the start of the electrical tripping impulse. Shutter speeds can be set at the factory at a predetermined value of from 1/200 sec to 1 hr, or can be furnished as a variable type from 1/200 sec to 1 sec. Both types can be furnished with provisions for holding the camera shutter open for the duration of the tripping impulse. Film transport which takes a maximum of 75 msec, occurs immediately after the cessation of electrical tripping impulse. The camera can be furnished to produce either single- or double-frame size records. The voltage required for the standard camera is 24 v d-c. The dimensions of the camera are approximately 11 in. $\times$ 12 in. $\times$ $6\frac{1}{2}$ in., and it weighs approximately $10\frac{1}{2}$ lb.

The Flight Research Engineering Corp, has produced a modification of the 16-mm GSAP Camera, their Model III,[96] permitting synchronous operation of a multiplicity of such cameras. The Standard Model III Camera operates at 10 frame/sec at an exposure time of 1/100 sec. Change gears are provided for 5 frame/sec and 20 frame/sec with an exposure time of 1/50 and 1/200 sec, respectively. Fifty-foot magazines of 16-mm film of the Syno-Pack, AN-A6, or Type G varieties, may be used. Another model may be supplied providing 4, 8, 16 and 32 frame/sec. Synchronous recording of images in a multiple camera chain to a shutter divergence of 5° maximum among all cameras is claimed. Flight Research Engineering Corporation has also disclosed a 35-mm counterpart of the above-mentioned camera, their Model IV, which is also designed for synchronous data recording using a multiplicity of cameras. Shutter accuracy is said to be maintained, among all cameras in a chain, to a maximum divergence of approximately 5°, or 1/700 sec at 10 frame/sec. "Master-slave" operation, single framing, fiducial marks and other characteristics of the 16-mm camera obtain. This camera utilizes standard 100-ft daylight-loading 35-mm film spools, and has the coding and timing marker lamps and the same frame frequency selection as the 16-mm Model III. This camera measures approximately $5\frac{1}{2}$ in. $\times$ $8\frac{7}{16}$ in. $\times$ $5\frac{11}{16}$ in.

An airborne synchronized motion picture system was described by White and Horwitz[97] of Northwestern University. Thirty-five-mm Eyemos fitted with 1/95-hp d-c motors, and 16-mm gun cameras driven by flexible shafts from separate drive units were operated at 20 frame/sec, one such unit driving two 16-mm cameras. A synchronization system said to be capable of producing shutter synchronization within one aircraft at frame frequencies of 20 frame/sec to within ± 0.002 sec is disclosed. Oscillographic recording for monitoring the accuracy of the motor control system, film coding for marking the film of different cameras for matching, a timing system relating all data to an accurate time base, and a plane-to-plane radio link for control equipment and relating data between two or more aircraft are part of this system. Phase differences between the cameras of two aircraft may exist, but the difference can be determined from the oscillograph records, as can the actual time of shutter openings for all cameras to 0.001 sec. Seventeen cameras were operated in the remote aircraft, and six in the parent. Gaseous-

discharge tubes were used to provide short-duration illumination of fast moving dials.

There appears to be considerable requirement for a more accurate synchronization and more insurance of frame-to-frame matching than exists in the systems described above. Work in this direction is currently under way and synchronization to better than 1° of shutter rotation is expected.

An automatic flight data-recorder for photographically recording instrument readings in aircraft during test flights was developed by Edgerton, Germeshausen, and Grier.[58,98] Electric motor drives were adapted to the standard 16-mm magazine Cine Kodak. Fast acting, overriding shutters were incorporated to give a short exposure despite the slow operating speed of one frame per second. Contact synchronizers with zero time delay were incorporated for synchronizing the electronic flash provided by a special gaseous-discharge tube utilizing only its infrared radiation. The instrument panel illuminated measures 11 in. × 14 in. The camera-to-panel distance is 36 in., the maximum aperture is *f*/1.9, and a 12-v battery source is used. The complete unit, which includes power supply, camera, lamphouse assembly and cables, weighs 18 lb. The lamphouse is covered with a Wratten 88-A filter, and is mounted directly on the camera. The camera lens is covered with a Wratten 88 filter, and infrared film is used. An input to the flash tube of 12- to 14-w sec is provided.

A modified Bell & Howell Filmo camera is used to determine space-time information in the study of aircraft takeoffs and landings.[58] Two 16-mm frames are recorded simultaneously, the upper portion carrying an image of the aircraft, and the lower, a series of instrument recordings giving information in the form of time, position of an azimuth scale, a wind velocity indicator, a wind direction indicator, a data card, and a film footage counter. A 4-in., *f*/4.4 lens is utilized interchangeably with 6-in., 10-in., or 12-in. lenses. Azimuth scale objectives are changed, depending upon the focal length used. An exposure of 1/200 sec at a frame frequency of 4/sec is characteristic of this camera. Satisfactory operation is said to be possible from −20° to +140 F. The capacity of this camera is 100 ft of film and the azimuth scale covers 146.6° of arc. The azimuth scale is set with the zero normal to the flight path, and the camera is panned in photographing the landing of the aircraft. A two-camera setup may be employed if the aircraft is not following a standard flight path normal to the zero of this azimuth scale.

Another space-time data-recording camera was designed by Neyhart of Guild Laboratories, similar in conception to the camera described above. This Photo-theodolite takes pictures at 0.1-sec intervals, and is provided with a glass grid of horizontal and vertical degree lines which are superimposed during exposure on a series of pictures of the takeoff and landing of the aircraft. The grid, in the form of a 160° segment of a circle, is provided with five horizontal lines, each representing 2°, and vertical lines, each representing 1°, recording to 80° either side of a 0° marker. By orienting this 0° mark at a known distance on a line perpendicular to the flight path, and locking it in place, the camera, which is free to rotate about the center of the lens, is used to record the aircraft characteristics under study. A special coaxial, double-drum shutter, situated between the lens and the film plane, makes one exposure per revolution. Reduction of data from these records, producing linear distance of airplane travel, is quite simple. By multiplying the tangent of the angle recorded on the film by the distance of the Photoscope Camera from the line of flight, the distance of the airplane from the intersection of the perpendicular camera line is determined. The dif-

ference in these two distances derived from any two consecutive frames is the distance traveled by the airplane in 0.1 sec. This type of photographic theodolite is finding considerable use in flight test programs.

G. Data Reduction Apparatus

Reduction of data from film has not received the impetus due it, although some progress was made in 1950.

Several instruments were announced of use in nuclear research. One is used in studying stereoscopic cloud-chamber photographs. In this device, described by Bromley and Bradfield,[99] the stereoscopic photographs are obtained by two modified 35-mm still cameras which are electrically operated. Means are provided for accurate location of the film in the focal plane. This two-camera unit is mounted in a replica of the chamber with the cameras' optical axes horizontal. A 10-in. × 12-in. ground-glass plate screen, free to rotate about a horizontal axis, is mounted on a movable base. Magnetic clamping devices permit orientation of the camera unit and screen to any desired orientation. Alternatively, a 12-in. circular enameled metal screen may be used. The screen may be rotated in all directions. The films are replaced in their respective cameras after processing and illumination sources fitted to the cameras. For each frame, the screen is moved to put the image of the top and bottom of the chamber into coincidence, and the distances from the film planes to the screen are adjusted to their original distance. With film positioning thus checked, angle and range measurements are made directly on the screen surface. Photographic records may also be made by placing a photosensitive material on the screen for the necessary exposure duration. To compensate for distortion caused by the plate-glass cloud-chamber roof, a similar plate is inserted at the proper point between screen and cameras.

A semiautomatic device for data reduction of nuclear phenomena was constructed at Columbia University and reported upon in the *Review of Scientific Instruments*.[100] In this apparatus, a microscope is fitted with a motor-driven stage which is moved by selsyn motors in x and y directions. The accuracy of this movement is said to be measurable to within 0.2 μ. These selsyns are fed from identical selsyn generators which are driven by a steering unit so that the photographic plate under study can be moved in any direction and with any desired speed up to approximately 25 μ/sec. The operator controls the direction and the speed of motion by a steering wheel and an accelerator pedal, and drives the nuclear track to be analyzed through a target. A recording-chart system, with the chart moving at 2000 times the speed of the microscope stage, permits the automatic recording of range, grain density and geometrical orientation of the tracks; 2 millimeters on the chart correspond to 1 micron on the photographic plate. The image of the plate is observed by the operator through an eyepiece and, at the same time, projected upon a small slit before a photomultiplier tube. The chart also records the angular position of the steering wheel and the vertical movement of the objective. Three-dimensional information may be deduced. The smallest slit reported upon is 1 mm long by 0.03 mm wide, covering an area on the plate of 0.07 × 0.02 μ (for a 2-mm immersion objective). Direct photometric comparison of the track against the surrounding background is possible where the accumulation of grains in the track is too heavy to be analyzed by counting individual grains. The method is said to produce reproducible results and a grain density record for a 2000-μ track may be made in about 10 min. Determination of coordinates may be accomplished with good accuracy.

A projector unit has been developed in Canada,[101] in which the film advance sprocket is driven by a reversible motor

and a glass pressure plate, holding the film in the projection plane, is released automatically while the film is being moved. The film spools accommodate 100 ft of 35-mm film, and take-up slack in both directions. Multiple record correlation may be accomplished by the use of several such units simultaneously.

One of the axioms of photographic instrumentation is that data should be recorded on film in such a form that rapid and accurate data reduction is possible. A device embodying this principle has been described by Benson[102] of the Douglas Aircraft Co. Information, such as telemetered quantities, is recorded on film in the form of a line perpendicular to the direction of film motion. The discrete value of the particular quantity is reported by the length of this line and a device has been built to permit automatic measurement of these lines, calibration of values, and plotting to suitable scales. In this device, 28 channels representing the readings from 28 instruments in a guided missile, for example, are recorded in a 35-mm continuously moving film camera. Thus, each frame consists of 28 parallel straight lines, each the recorded image of the motion of a light spot appearing on a cathode-ray tube. About 32 such frames are recorded per second. The automatic analyzing machine counts progressively through a frame to locate the required line, measures its length, and plots the associated value after suitable modification by preset 0 and scale factors. About 40 points are plotted per minute with an accuracy said to be better than $\pm\frac{1}{2}\%$ of full-scale deflection. The device embodies some 14 memories for calibration purposes, and about 5 distinct sequential thought patterns for selecting lines, controlling measuring cycles, and so on. In addition, some 5 discriminative thought patterns are involved to detect errors. A film projector and screen, using a photoelectric cell, counting circuits and electronic measuring networks, accomplish the reduction. This device normally plots six channels through one run of the film through the machine, and six different colors are used for the resultant plot. It is stated that an experienced operator can adjust the machine in about 15 min. A man-hour ratio of more than 5 to 1 in favor of this automatic method over previously employed manual data-reduction techniques was said to show a saving of over $9000.00 for a single record.

A device which permits automatic selection of microfilm frames and automatic photographic copying has been developed.[103] For such applications as literature research, microfilm copies of papers are photographed together with a code consisting of a series of light and dark squares. A scanning device, preset to react to a given coding, rapidly picks out the desired frames, and photographs them by means of a gaseous-discharge tube flash on 35-mm film. In this fashion, a single microfilm roll containing all papers on a given subject may be produced in a minimum time.

H. Shadowgraph

Shadowgraph instrumentation has long been employed for aerodynamic studies. Several embodiments of this technique were disclosed in 1950.

The pressurized ballistics range at the Naval Ordnance Laboratory[104] consists of a steel tube 3 ft in diameter, and over 300 ft long. Pressures from 1/100 to 5 atm may be employed in this tube. Twenty-five photographic stations, each fitted with a light screen and photocell, were designed to initiate a microsecond spark flash. The missile's shadow is recorded directly on a vertical photographic plate and on a similar horizontal plate by means of a mirror. Fiducial marks permit accurate coordinate determination. The duration of the spark source is said to be of the order of 0.5 μsec and it is of high intensity. An electronic chronograph is used to measure the time required for the missile to pass between two stations, measuring inter-

vals up to one second with an accuracy of the order of 0.1 μsec.

The second ballistics range reported on is that for the study of rockets at the Naval Ordnance Test Station, Inyokern.[105] A new type of silhouette procedure is employed for the determination of position and orientation of rocket models in transonic and supersonic flight. Measurements on the photographic plate to within $7\frac{1}{2}$ μ were found to be necessary. A multiple flash stroboscopic lighting technique using gaseous-discharge tubes and low-cost reflex reflectors for improvement of image-background contrast are employed.

Space-time data are being obtained in the Supersonic Free Flight Wind Tunnel at the Ames Aeronautical Laboratory[106] by means of a four-station shadowgraph and an associated chronograph. As the model flies by each station, a light screen initiates the spark-flash recording of the missile in flight on photographic plates. Some of the spark source light is recorded on a separate 35-mm chronograph. At the same time, an H-6 mercury lamp is pulsed at any desired frequency from 10,000 to 100,000 cycle/sec to provide a time base. Fiducial marks permit coordinate measurement. In addition to these four shadowgraph stations, three lateral photographic stations make possible the reduction of the three-dimensional flight path. From this flight path, lateral and vertical accelerations, hence side force and lift, can be obtained. Other quantities may be deduced.

Shadowgraphic techniques were employed at Naval Ordnance Laboratory to study the characteristics of water entry of spherical missiles at supersonic speeds.[51,107] Missiles shot into water at velocities of 7000 ft/sec were recorded at exposure durations of less than a microsecond.

Normal burning velocities of propane-air flames have been measured from shadowgraphs.[108] The previously employed stroboscopically illuminated-particle method of measuring the normal burning velocity by the heat capacity of the particles is said to be limited. A supplementary method is used to define the flame area. The line between the dark and light spaces on shadow photographs taken at different distances from the film to the flame defines this area, which is then extrapolated to the diametral plane of the flame.

I. Schlieren

Considerable activity in the improvement and extension of the schlieren system was reported in 1950.

A system employing multiple slit-gratings replacing the conventional knife-edge elements was described by Mortensen[109] of the Midwest Research Institute. A number of advantages are claimed, particularly that larger-sized working fields can be achieved with an objective lens of given aperture. Greater intensity of image illumination is obtained in some cases, and usually the overall length of the system can be reduced.

A variable-focusing schlieren system was developed at Cornell University,[110] which is able to distinguish between the density gradients occurring at various positions along the light path. This schlieren system utilizes multiple light sources and corresponding cutoffs to achieve this variable-focusing effect. The source plate has 82 slits, of which about 50 are illuminated, while the cutoff plate provides for 82 corresponding knife edges. Each source-cutoff combination produces an independent schlieren image, and for a given screen position, the shadows produced by density gradients at a single plane in the field superpose exactly. In general, for planes out of focus, offset superposition of the images blurs out the effects of density gradients not in the focal plane by a process similar to the focusing of ordinary lenses. This system has not been very effective in studying boundary layer phenomena.

A conventional schlieren system employed in connection with a shock tube for the study of two-dimensional wave

propagation was reported upon by Cornell University staff members.[111] A spark source discharged 1.7 μf (microfarads), charged to about 9 kv, for an exposure duration of the order of 1 μsec.

A French governmental laboratory[112] has reported upon its schlieren system used for the study of supersonic flow. This system comprises essentially a controlled-arc source of light, and a double field lens (diameter, 21 cm, focal length 1.5 m) producing an image which is shielded from the light source by a screen having almost the same dimensions as the image. A projection objective is used to obtain an image of the surface to be studied on a screen between the field lens and the primary image. Cinematographic recordings have been employed.

The Langley Aeronautical Laboratory, NACA, has reported[113] on its schlieren and other flow visualization techniques. Their experience with the 11-in. wind tunnel indicates that the limit of usefulness is reached at a pressure of about 1 mm of mercury for slender test models at M = 7.0. At these conditions, good results have been achieved by the use of a double-pass system which has proven of use at M = 10 for a 50-atm (atmosphere) stagnation pressure. For higher tunnel speeds, the nitrogen afterglow technique[114] has been employed. Schlieren afterflow photographs have been obtained at low pressures. Examples of applications of schlieren systems to various aerodynamic flow studies are given.

High-speed schlieren motion pictures were used at New York University,[45] together with instantaneous pressure measurements, to study flame structure and flow in half-open tubes. The high velocity flames were produced by placing a grid augmenter in the path of an advancing flame front. Frame frequencies in the Fastax range were employed.

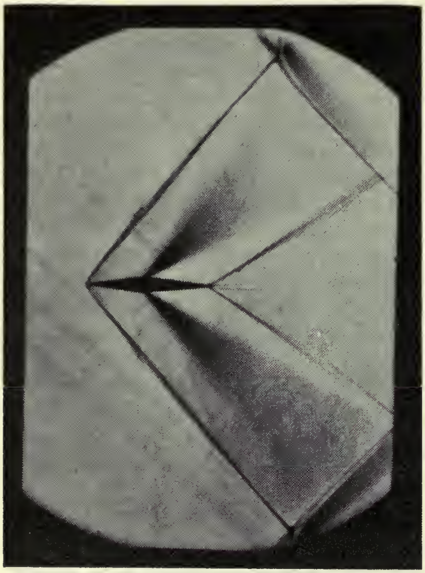
In other flame studies,[115] schlieren photography has been used to measure the spatial velocities of flames moving in mixtures of nitrogen dioxide and formaldehyde, at initial pressures of 4 to 8 cm of mercury in a spherical vessel.

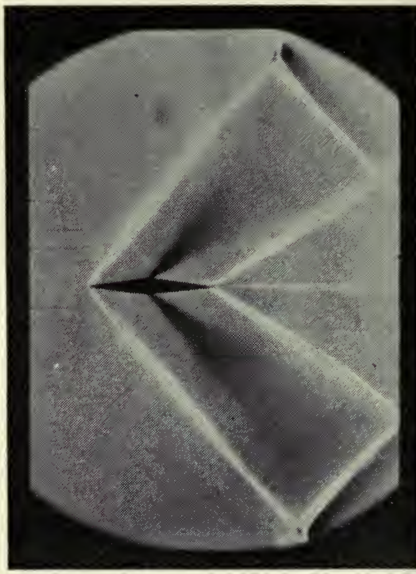
The schlieren technique has also been applied[116] to the measurement of radial variations of gas temperature in arcs. Currents varied from 2.9 to 20 amp, and the gas temperature was 4000 K at about 4 mm from the discharge axis, falling to about 200 K at about 2 cm.

The use of a phase plate replacing the knife edge in a schlieren system for use in microscopy has been extensively investigated.[117–119] Improved sensitivity is said to result.

Considerable interest has been shown in color schlieren systems. The conventional schlieren system, recording only brightness, is affected only by the components of the deflection at right angles to the knife edge. With a color schlieren system,[120] using an illuminated color circle in place of the slit, and a circular aperture in place of the knife edge, the hue and saturation of an image will indicate the direction and magnitude of the deflection. This system has been applied to microscopy.

The National Physical Laboratory at Teddington, England, has disclosed[121] a color schlieren system found to be useful for flow investigations in a high-speed wind tunnel. Using the standard off-axis schlieren system, a white-light source is dispersed by a prism, and the parallel beam of light passed through the working section. A plane mirror is used in connection with a slit and camera lens to bring the color schlieren image to focus on a photographic plate. The image of the source thus formed ahead of the slit consists of a series of colored bands and the slit, placed in the focal plane, is adjusted to cut off all the light except that of a particular color. When the density gradient in the working section is uniform, the image on the screen is monochromatic and uniformly illuminated. But, with the introduction of schlieren, the corresponding image of the source shifts relative to the slit, and the corresponding part of the image on the





Figs. 6 and 7. Black-and-white reproductions of color schlieren photographs showing flow around a 12% double-wedge aerofoil at a Mach No. of 1.6. The originals were made on 35-mm Kodachrome. (Courtesy of R. J. North,[121] Aerodynamics Division, National Physical Laboratory, Teddington, England.)

1. Background—yellow
2. Light to dark gray areas—green
3. Leading and trailing shock waves—dark orange

1. Background—green
2. Light to dark gray areas — blue
3. Leading and trailing shock waves—yellow

photographic plate changes color. Good results are said to have been obtained using a 48-w projector lamp as the light source. The quantitative use of this system may be achieved by moving a slit across until a particular color disappears from a point in the image on the photographic plate, thus determining the displacement of the corresponding image of the source in the focal plane of the second mirror. Figures 6 and 7 are color schlieren photographs presented through the courtesy of the National Physical Laboratory.

Another color schlieren system producing quantitative results has been disclosed.[122] This system utilizes a dispersing prism to illuminate the field, and a slit in place of the usual knife edge. The normal field will then be colored and any deviation will be shown as a change in this color. If a second dispersing prism with its axis at right angles to the first is placed near the image plane, deviations will be recorded as small spectra whose lengths are a measure of the deviation. Using a source with a number of discrete spectrum lines, the schlieren field will show colored contour lines whose deviation can be found from the known wavelengths.

J. Interferometry

Interferometric methods have proven of particular interest in the study of aerodynamic flow and are finding other applications as extensions of earlier work in such fields as the study of metals, surface polish, hardness testing, and the formation of slip bands in stressed metal-

lic crystals.[123] This latter technique of multiple-beam interferometry has also proven of use in the study of thin-film thickness measurements,[124, 125] and indicates utility as a stage micrometer.[126, 127] It has also been used in studying the mechanism of crystal growth in certain minerals, the examination of defects in mica, and the modes of oscillation of quartz.

In aerodynamic investigations, a modification of the standard Ronchi schlieren two-mirror technique has resulted in the development of a new, low-cost, large field diffraction grating interferometer.[128] In this system, a monochromatic source and a pair of replica transmission gratings (2000 lines/in.) are used in conjunction with the standard two-mirror schlieren system, with the diffraction gratings placed axially in the light path between the two mirrors. Interference fringes consisting of two sets in each field image result, slightly overlapping at the center of the field, with one set being the complement in intensity of the other. The presence of the two sets of fringes limits the useful field in this particular apparatus to approximately $\frac{1}{3}$ the area of the 18-in. diameter schlieren mirrors employed.

A Mach-Zehnder interferometer, modified for photoelastic purposes, has been investigated theoretically by Saenz[129] of the Naval Research Laboratory for use in the analysis of residual stresses in quenched glass objects, which are so highly quenched that their explosive characteristics would prevent the use of cutting techniques for the measurement of these stresses. Promise is indicated in the adaptation of this technique to the study of transient thermal stresses in cylinders, particularly when the temperature differences are so large that thermal and elastic constants of the material vary considerably and the radiation at the surface does not follow the simple Newton Law of cooling, so that the Stefan-Boltzmann Law must be employed. Present photoelastic techniques do not permit ready determination of such thermal stresses.

The interferometer has been used at the Ballistic Research Laboratories at Aberdeen[130] in the study of approximately axisymmetric flow at various Mach numbers about a cone-cylinder in free flight. Plotted fringe shift data from the region near the nose of the cylinder fall into a narrow band indicating approximate conicity. They also check closely the corresponding theoretical fringe shift data calculated for Taylor-Maccoll flow.

K. Medical

In the medical field, a rather large number of medical still cameras have appeared on the market, all essentially using the same embodiment: namely, a single-lens reflex 35-mm camera together with two light sources close to the lens, all held on a common base.[131] Modifications of this lighting system have been developed, using a circular electronic flash tube disposed annularly about the lens.

In June of 1950, Neyhart[132] described an advance over previous systems for body-cavity motion picture photography utilizing a coaxial light source and taking-lens system. This camera is a combination of a 16-mm magazine-loading electric camera and a projection-type light source and optical system. The unit provides a beam of collimated light which is coincident with the camera lens cone, the two cones being identical in space. Thus, the field area illuminated by the beam is identical with the area photographed by the camera and varies in width from $1\frac{1}{2}$ in. to $4\frac{1}{2}$ in. at camera distances of from 10 in. to 30 in., respectively. In this system, light from a 1000-w lamp is collimated through a condenser and projection lens and passes through a special transmission-reflection mirror. This mirror consists of alternate clear and silvered bands which accomplishes both the passing of half the light and reflection of the subject, using a

mirror and taking-lens system, to the film. The projection and taking lenses are mechanically coupled and the camera permits viewing of the subject continuously during photography by both camera operator and surgeon. It has been applied to shadowless photography of natural body cavities, and cavities resulting from surgery, which can be visually examined without the aid of optical instruments.

The Bausch & Lomb Optical Company introduced its new retinal camera during 1950, employing fundamentally the principles of the Zeiss-Nordensen retinal camera.

A semiautomatic camera for still photography of surgical procedures was developed at the Mayo Clinic.[133] This camera, utilizing flash lamps dispersed about the lens, is housed in a sterilizable blimp.

An accessory for medical photography, the Kamm Stand, was described by Hansell.[134] This camera stand provides a rigid support for a camera to be placed at any point within a sphere of a 4-ft radius. It will also support the weight of at least one camera operator in several positions.

A most interesting paper appeared in the *British Journal of Photography*[135] concerning the application of photogrammetric techniques to medical research. The use of automatic plotting apparatus and stereogram pairs taken on fine-grain film has produced particularly accurate physical measurements of surface areas and of individual cells. It was stated that the location of a point can be determined with a mean error of ± 0.005 mm or $\pm 0.03\%$ of the camera-to-object distance.

Infrared photography has been applied to clinical investigations in the medical field[136] where it is possible to show comparatively superficial vascular changes, mainly in the subcutaneous veins. Applications have been made in anatomical, physiological, pathological and clinical fields.

L. Microscopy

Microscopy in its various stages will be dealt with very briefly. A large number of papers have appeared in 1950 in this field, and a few are listed in the bibliography of this section.

Recent developments in light microscope instruments were discussed by Foster of Bausch & Lomb.[137] New objectives for ultraviolet microscopy and phase-contrast microscopy were described. Silge and Kuhn of San Francisco brought out their Orthophot,[138] a relatively inexpensive photomicrographic apparatus, and the American Optical Company announced their new inverted metallograph.[139]

Resolution of microscopic systems has been more thoroughly investigated[140] and it was found that the resolving power of the microscope is underestimated by the classical theory.

The use of a Western Union point source for photomicrography was disclosed by Weber in the *Journal of the Biological Photographic Association.*[141]

The applications of photomicrography were many as reported in the literature of 1950, and included technique information in such fields as metallurgy,[142] dental microscopy,[143] and in the study of the crazing of polystyrene specimens.[144] (This latter study utilized the light microscope, the electron microscope, and the X-ray spectrometer.) Photomicrographic techniques were used to study the solidification of small metallic droplets at the General Electric Research Laboratory.[145] A special high-low temperature microscope stage was developed in order to study specimens from the temperature of liquid nitrogen to an upper temperature determined by the melting point of the specimen.[146] Surface tension effects in thin silver films were studied, using both bright field and polarized light microscopy and electron microscopy.[147]

Phase microscopy came in for further investigation during 1950, and a number of papers appeared in the *PSA Journal*,[148]

Journal of the Optical Society of America,[149,150] and the *Comptes Rendus* of the Academy of Science, Paris, France.[151,152] The *PSA Journal* article by Richards[148] disclosed the use of an FT-230 gaseous-discharge tube used for phase photomicrography, including time-lapse motion picture techniques. Benford and Seidenberg[149] of Bausch & Lomb described the application of phase-contrast microscopy related to opaque specimens, while Saylor, Brice and Zernike[150] discussed the requirements and applications of color phase-contrast microscopy. This latter technique permits clear distinction between effects caused by scattering or general absorption and those caused by small differences in refractive index or thickness. The *Comptes Rendus* papers disclose an apparatus taking the place of the eyepiece to give images in variable phase contrast,[152] and a second apparatus, which is independent of the microscope, utilizing a phase plate of variable absorption.[151]

A wide interest in ultraviolet microscopy is evidenced by the literature. Grey of Polaroid described newly developed objectives of catadioptric type of intermediate numerical aperture.[153] The color translation microscope of E. H. Land, previously disclosed in 1949, was the subject of a brief review by W. F. Berg.[154] R. C. Mellors,[155] working at the Sloan-Kettering Institute for Cancer Research, gave a rather extended paper on the reflecting microscope used for qualitative and quantitative ultraviolet microscopy. An apparatus employing visible phase focusing and allowing a series of photographs in the ultraviolet range together with step-wedge calibrations to be rapidly taken, was designed for the ultraviolet photomicrography of living cells.[156] Tumor tissues were also studied in visible light by means of a phase contrast searcher and photographed at 2570A using a quartz monochromat.[157] Jones of Kodak Ltd.[158] described techniques employed in the ultraviolet photography of hot metal surfaces.

Considerable progress was reported in electron microscopy during 1950 with the introduction of the Philips 100-kv electron microscope,[159] the RCA 50-kv table model,[160,161] the 100-kv three-stage electron microscope built by Metropolitan Vickers of England,[162] and the field electron microscope of Muller of Germany.[163] The light microscope and the electron microscope were compared by Marton[164] of the Bureau of Standards, and modifications, techniques and applications were discussed in many other papers.[165–180]

The X-ray microscope was also under further investigation during 1950 and some progress has been reported.[181–184]

An exposure meter for photomicrography was reported in *Electronics* in January 1950.[185]

A two-wavelength microscope has been devised[186] in which light of one wavelength is permitted to flow as far as the diffraction image of the object. The light of a second wavelength is substituted to this plane, and continues to flow through the rest of the optical system. In this case, the magnification depends not only on the image-to-object distance ratio, but also the ratio of the wavelengths used. Using X-rays and visible light, the magnification is of the order of 3×10^5. Studies of the structure of marcasite were made.[187]

An observation chamber for ultramicroscopic investigations on aerosols was reported,[188] and techniques of microspectroscopy,[189] and infrared microspectroscopy[190] were described.

M. Radiographic

A review of recent developments in medical photography and radiography was made by Watson[191] of England. A number of new X-ray devices were disclosed during 1950 including a 70-mm fluorographic camera[192] employing a curved mirror and correcting lens of the Schmidt type, having an effective aperture of $f/0.75$. This camera is made by De Oude Delft in Holland. The film is held in a curved pressure plate, and a

resolving power of 30 lines/mm at the center and 25 lines/mm near the edge is claimed. The trend in fluorographic recording, the indirect X-ray recording method, has been toward Schmidt optics of high aperture.[193] Fairchild, in this country, has disclosed such a camera.

One of the important problems under investigation is the amplification and intensification of the X-ray image. Further work during 1950 indicates strides toward this realization. The use of the image-converter tube for fluorescent image intensification was described by Rawlins[194] and was shown to produce an intensification of some five-hundred-fold at the most, bringing fluoroscopic observations to a brightness of about 0.1 mL (millilambert). Moon,[195] in this country, described the use of a scanning X-ray tube to accomplish the same end.

Several general papers on the subject of the generation, of properties of X-rays, and their application were presented by Tasker,[196, 197] and by Meakin[198] (on the subject of megavolt radiography).

X-ray photographs of the vocal tract[199] were used to determine the dimensions for each vowel permitting calculation of resonances in the study of normal speech. From these data, an electrical circuit has been made to produce acceptable vowel sounds.

Cineradiographic devices were described by Campbell,[200] L. Reynolds, et al,[201] R. J. Reynolds,[202] Janker,[203] and in *Engineer.*[204] Essentially, all these workers are utilizing the indirect method in the studies of medical subjects to frame frequencies of the order of 50 frame/sec. In most cases, a high aperture lens of the order of *f*/1.0 or faster, is employed.

Such a device is also described in *Electronic Engineering*[205] built by Watson and Sons in England. This device uses a 120-kv, 400-ma X-ray tube and a 35-mm motion picture camera fitted with a 4-cm *f*/1.5 lens, photographing the fluorescent screen image. The X-ray tube is excited only during the camera shutter-opening. Variable frame frequencies from 3.125 to 50/sec have been obtained.

A 120-pulse X-ray tube is synchronized with a motion picture camera in a device for cine fluorography for clinical use, recently described.[206] In this system, after an exposure to 4 pulses of X-ray, the current is shut off for the next 4 pulses while the film is being advanced. For circulatory studies, 15 frame/sec is used, and 30 and 60 frame/sec have been achieved, again using the indirect method.

An electronically controlled cineradiographic device described by Quittner[207] permits pulsing of the X-ray tube for exposures of 3/sec upward.

High-speed flash radiography providing exposure durations of 1 μsec or less were described by Pollitt[208] in England, and Clark[209] in the United States. Exposure durations as small as 0.1 μsec have been produced and applied in the study of explosive phenomena, projectiles in flight, and similar high-speed phenomena. Impulse X-ray tubes providing microsecond pulses were described by Funfer.[210] A million-volt resonant cavity X-ray tube was described by Mills[211] for use as a radiographic stroboscope for the study of objects in movement.

X-ray flash photographs of explosions in water at exposure durations of 2 to 3×10^{-7} seconds were employed by Schall.[212] Shock-wave velocities up to 6600 m/sec and impulsive pressures up to 190,000 atm are obtained in water by means of an explosive charge The velocity of an advancing shock wave is a function of position and density variations measured from the X-ray photographs, permitting pressure-density relations for high pressures to be calculated.

The use of radioactive isotopes in industrial radiography has been given considerable impetus and was reported upon by Tenney[213] of Los Alamos. Image formation by means of X-rays was further investigated by Cauchois,[214] and a method permitting chemical analysis by means of X-rays was reported upon by

Alvarez.[215] In this latter method, the concentration of an element in the anticathode of an X-ray tube is directly proportional to the photographic density produced by the characteristic X radiation of this element. Two photographs are taken, one recording the density of the unknown quantity of the element and the second photograph showing the density for a known quantity of the same element.

An X-ray tube producing a convergent beam of X-radiation in the form of a hollow cone was developed at Syracuse University.[216] The light energy and spectral distribution of four different types of X-ray fluorescent screens were investigated,[217] and the quantum efficiency in photographic X-ray exposures was further investigated by Bromley and Herz.[218]

N. Underwater

Several underwater cameras were disclosed during 1950. Chesterman[219] described a motion picture camera having a 100-ft film capacity enclosed in a watertight casing with a self-contained electric drive. Focusing and stop controls were brought to the outside. The camera was slightly positively buoyant and could be operated by a diver with air-breathing equipment to permit work down to a 45-m depth.

Bucher[220] employed a Rolliflex in a suitable housing for still photography to 20 m in depth and describes color work when very high intensity conditions obtained at *f*/4.5 and 1/50 sec. Jenner[221] described a still camera fitted with a battery-capacitor flashlamp illumination system containing six flashlamps to provide for color photography in as short an elapsed time as 3 sec. The apparatus is contained in a transparent plastic cylinder.

Underwater black-and-white and color photography was accomplished[222] in Germany using a Robot Camera synchronized with gaseous-discharge tubes which could be discharged at intervals of 8 sec. Hahn of the Woods Hole Oceanographic Institution[223] discussed some of the aspects of underwater photography at great depths. Various cameras were used including the Robot, reflex cameras, and 16-mm and 35-mm motion picture cameras. Illumination was provided by flashbulbs or gaseous-discharge tubes. Interesting sea life and geological studies have been made.

Collins of the Royal Naval Scientific Service[224] describes much of the work that has been accomplished to date by the British Admiralty and in liaison with the French Navy. The spectral transparency of different waters was investigated and photometric studies were carried out. Sunlight and artificial illumination provided by various sources, including 250- and 400-w mercury arcs and 45-w sodium-vapor lamps, were used and 35-mm still and 16- and 35-mm motion picture cameras and shallow-water diving apparatus were employed.

Conger, of the U. S. Naval Photographic Center[225] described, before this Society, the new Aquaflex 35-mm underwater motion picture camera designed and built by Eclair of France. This device permits photography from 8 to 40 frame/sec and has a capacity of 400 ft of film. The Aquaflex is housed in a specially designed container having a supply-demand type compressed-air valve regulated to provide 3 lb/sq in. over sea pressure at the depth of the camera. The air supply is carried in a charged cylinder under the container. A reflex viewfinder permits viewing during exposure and controls are available external to the case.

O. Photosensitive Materials and Treatment

A new film base was developed by Armour Research Foundation[226] for the U.S. Army Signal Corps. The material used is *n*-propyl cellulose, which was stated to work successfully in laboratory tests for wear at temperatures ranging from $-65°$ to $+140$ F.

Speed, contrast, and graininess in the ultraviolet region of 2650 A, were measured by R. D. B. Fraser in England,[227] for 10 motion picture emulsions. The number of photographs which may be obtained for a given radiation dosage is an important characteristic of an emulsion in the ultraviolet cinephotomicrography of living cells. Fraser derived an index useful as a guide to this quantity.

Ultraviolet photographic plates introduced in 1949 and described in 1950 by Schoen and Hodge[228] are made to be sensitive to the very short ultraviolet wavelengths which can only be photographed in the vacuum spectrograph. The plates depend on having the minimum amount of gelatin covering the silver halide of the emulsion to reduce ultraviolet absorption by gelatin to a minimum.

Polaroid-Land film, Type 41, producing black-and-white prints was introduced.[229]

Two new nuclear emulsions were developed by Eastman Kodak, the Type NTB2 and the Type NTC3 plates.[230] The latter is designed to record low-energy alpha particles and low-energy protons to 7 mev.

Kodak autoradiographic plates, Type A and Type No Screen, for use in radioactive isotope research, were also made available.

In addition, a high resolution emulsion for autoradiography was described by Berriman, Herz and Stevens.[231] This material consists of a glass support carrying a strippable 10-μ gelatin layer which carries on its upper surface a 4-μ thickness of fine-grain concentrated emulsion. The characteristics of this emulsion have been investigated and the resolving power measured by making autoradiographs from radioactive test charts producing a value of at least 200 lines/mm. A method of preparing an emulsion for the recording of nuclear particles is described by Demers.[232] It is stated that this emulsion is sufficiently sensitive to record electron tracks at energies down to 1.8 times the minimum ionization energy.

The spectral sensitivity of Kodak No Screen and Kodak Industrial Type K, X-ray films were determined[233] in the region between 0.2 and 2.5 A.

Latensification with ozone, producing speed increases from 9 to 100%,[234] gold sensitization of X-ray films,[235] and a brief review of treatment of under-exposed negatives[236] were described in other papers presented in 1950. The combined effect on the latent image of infrared radiation and intensification was investigated by the Eastman Kodak Research Laboratories.[237]

The use of 6-nitrobenzimidazole and benzatriazole as antifoggants is discussed by Schantz,[238] while ion-exchange methods used for the reclamation of wash water were described by Levinos[239] of Signal Corps Engineering Laboratory.

Double development of nuclear emulsions has been investigated by Jech.[240] Uniform development throughout the depth of nuclear emulsions has been difficult to achieve. Stevens[241] of Kodak Ltd. has investigated temperature coefficients of swelling and development in 100-μ NT1 nuclear plates.

Low-intensity reciprocity failure investigations continued, with papers by Katz,[242,243] and Webb.[244,245] Milne of the Institute of Optics, University of Rochester,[246] studied a new reciprocity failure in exposure at high intensity and short duration. For simple blue-sensitive emulsions, the reciprocity law is found to be valid for exposure times somewhat shorter than 10^{-5} sec. However, in the case of Super XX (dye-sensitized emulsions), a new reciprocity failure is observed for exposure times shorter than 10^{-6} sec and amounting to 0.2 to 0.3 log units of exposure referred to a density of 1.0, for exposure times of 10^{-6} sec. Exposures made with the aid of filters indicate that this failure occurs only for that part of the exposure contributed by the sensitizing dyes and does not occur for

exposure to blue light absorbed directly by the silver halide.

P. Special Photosensitive Systems

The metal diazonium process was further described by the Philips Research Laboratories.[247,248] This system of photographic reproduction has particularly high resolving power (of the order of 1200 lines/mm). Cellophane may be used for the film base, and the system applied to such applications as sound-on-film recording, microfilming, and other processes where a high resolution is of importance. It is understood that the Philips Research Laboratories have discontinued their technical development of this system. This system offers interesting possibilities and we hope that means may be found to continue investigation.

Xerography, previously disclosed, was the subject of a brief review paper in 1950.[249] Continued development of the process has led to its application in radiography.[250] In Xeroradiography, a metal or transparent support is coated with a semiconductor sensitive to X-rays, which is sensitized by charging it. This surface charge is discharged into the conductive backing in areas exposed to X-rays. The resultant latent electrical image is developed in a few seconds by flowing a resin powder over it which clings to the still-charged regions. Paper prints may be made by transfer of resin. It is claimed that the speed of Xeroradiography exceeds that of most nonscreen X-ray emulsions, that the contrast sensitivity is better than the 2% required for aircraft inspection, and that the resolution exceeds 200 lines/in.

Kaprelian[251] of the Signal Corps Engineering Laboratory presented an extensive survey of photographic processes and materials and of unconventional processing systems.

Q. High-Speed Processing

Much attention has been given to the development of apparatus and techniques for rapid processing of emulsions.

A self-processing camera was described by Jackson[252] intended to give developed photographs of shell bursts or PPI cathode-ray pictures on 35-mm film within 15 sec after exposure. The film is exposed and then passed through a thermostatically heated developing tank, and thence to an illuminated viewing position after excess solution has been removed by passage through a light-tight roller squeegee. The film must be lowered into the developer simultaneously with the start of the film through the camera, and must be lifted out just before the film comes to rest to prevent melting the emulsion. The developer is used at 100 F, and consists of Johnson's M.Q. undiluted, and contains 6%–7% of caustic soda. Fixing is accomplished with an acid potassium iodide bath. The image thus consists of black-developed silver against a yellow background of silver iodide and is stable to further light action.

Levinson[253] of Kodak Ltd., described the development of a small continuous processing machine for the development of paper or film of 35-mm width or less, which has no sprockets, and is not restricted to one width of film at a time. This device is of flexible construction permitting rapid modification to suit particular needs. Provision is made for eleven tanks, 4 in. square of 11-, 6-, or $3\frac{1}{2}$-l capacity, which have three hose connections to allow variation in agitation and circulation. Speeds from 3 in. to 15 ft/min are obtainable.

Levinson[254] also discloses a compact device for the rapid processing of 35-mm paper in roll form. The unexposed paper is passed into a small tank containing a developer and thence over a large heated drum to a take-up reel. The exposure is made after the paper passes through the developer and immediately upon contact with the drum. A paper speed of 25-mm/sec and a developer temperature of 43 C are used. The trace is visible in half a second at $12\frac{1}{2}$ mm from the point of exposure.

Sixteen-mm motion picture film may be processed in a new rapid film processor developed at the General Precision Laboratory in Pleasantville, N.Y.[255] A hardened emulsion (Eastman Fine Grain Release Positive Film, Type 7302) is processed at elevated temperatures of the order of 120 F; a total processing time of 40 sec between input and output ends of the processor obtains. The linear speed of travel of the film through this processor is 36 ft/min, corresponding to 24 frame/sec. The device has been used in the intermediate-film theater television system.

Ives and Kunz of Eastman Kodak[256] described recent work on rapid processing methods, and indicated that the times of treatment can be reduced by a factor of 25 to 50.

Leonhard Katz of the Raytheon Manufacturing Co. has disclosed the use of high-speed turbulent film drying and processing based upon his theoretical and practical research in molecular diffusion processes.

Tuttle and Brown of the Kenyon Instrument Co.[257] have developed a high-speed processing system utilizing vacuum injection of the processing fluids. In the embodiment they disclose, a 35-mm motion picture film carried in roll form is exposed through a self-contained lens, successively stepped to three vacuum-injected processing fluid stations, and thence to a dryer and projection system. The total time elapsed between start of development and projection may be of the order of 4 sec.

Stabilization processing to produce images of moderate stability without washing was reported on by Russell, Yackel and Bruce.[258]

The Engineering Division, Photographic Laboratory, of the Air Materiel Command reported a new Ansco Color Film processing method in which the processing time of 90 min originally taken was reduced to 20 min. A prehardened emulsion permits 80 F processing.

A relatively rapid film drying process applied to X-ray sheet film was described by Davies and Soper.[259] A 25% solution of diacetone acohol in petroleum ether is used, the film immersed after washing and blotting and withdrawn 1 min later. The water is effectively removed from the swollen gelatin layer and wiping with a soft cloth readies the film for projection and handling.

R. Optical Elements

In 1950, a number of interesting objectives were developed. A relatively simple variable focus lens was described by Cuvillier,[260] the Berthiot Pan-Cinor. This lens provides for a transmission of 85% and focal lengths of 0.8 to 2.4 times the focal length of the associated objective lens. For example, a Pan-Cinor lens for 16-mm film of nominal focal length of 25 mm, provides focal lengths of 20 to 60 mm. The aperture of this lens is *f*/2.8. Wide-angle and telephoto types have been developed.

A wide-angle underwater lens was developed by Thorndike,[261] covering a half field of $37\frac{1}{2}°$. The area imaged with this lens is more than seven times that covered with the customary arrangement of a conventional camera lens behind a plane window.

Considerable further development of Schmidt objectives was disclosed in 1950. Wormser[262] described the design of a wide-angle (40°) Schmidt system having a focal ratio of *f*/0.7. Seegert[263] reviewed progress in the development of wide-aperture photographic objectives and Paul[264] reviewed current designs of catadioptric objectives. A refractive lens of aperture *f*/1.0 has been described,[265] the Tachonar, and is available in focal lengths of 25, 50, and 75 mm.

Interference filters permitting the transmission of narrow-wavelength bands or for the exclusion of infrared, have been introduced by Fish-Schurmann, Bausch & Lomb, and Baird Associates, and have been described by Greenland and Billington[266] of England, and Roig and Des-

camps[267] of France. An interference mirror used in an arc projector to transmit infrared and reflect the visible spectrum was described by Koch.[268]

The use of the electrooptical shutter has been applied by Babits and Hicks of Rensselaer,[269] using ADP crystals, for the production of electrically controlled color filters.

S. Light Sources

A number of interesting light sources and their applications were described in 1950. A high-intensity spark source, providing an effective duration of the order of 10^{-7} sec has been developed at Catholic University.[270] The system used permits a much more intense source than has been previously developed.

The light emission from high-current spark discharges of the flash-tube type, has been studied by Glaser.[271,272] Sparks obtained with the discharge of the large capacitances (0.01 to 5 mf at 2 to 15 kv) through gases at 1 to 17 atm were studied for spectral emission. Additionally, oscillator discharges were studied. The FT-110 flash tube providing for high efficiency at low voltage was described by Noel and Davis.[273] Barstow[98] applied a very small quartz tube designed specifically for an infrared instrument recorder. The use of the gaseous-discharge tube as a light source for motion pictures was analyzed by Carlson and Edgerton,[274] while Olsen and Huxford[275] of Northwestern University measured the electrical and radiation characteristics of flash discharges in quartz tubes filled with rare gases at pressures of about 100 mm of mercury.

Laporte has applied xenon flash tubes to photomicrography at repetition rates up to 25/sec,[276] and has investigated[277] the use of the gaseous-discharge tube for projection at 24 frame/sec, a flash tube operating at 48 flashes/sec has been employed. An embodiment of this nature was described in a German journal by Hagemann[278] in a continuously moving film projector.

A compact source lamp described by Bourne and Beeson[279] has been employed for high-speed motion picture photography. This device, named the Cine Flash, permits the flashing of two compact source mercury-cadmium lamps operated in series at their normal wattages of 1 kw as continuous sources, and then flashed at 3, 5 or 10 kw for 5, 2 or 1 sec. This light output is sufficient for color photography at speeds up to 3000 frame/sec or for black-and-white photography with small lens apertures to give considerable depth of focus.

General Electric introduced a schlieren light source utilizing their H-6 mercury lamp.[280]

Hoyt and McCormick[281] have made an intensive study of the dependence of peak intensity and duration of the visible light from arcs of a few microseconds' duration in xenon, krypton and argon on the input energy, the circuit characteristics, the gas and the pressure. The ultraviolet radiation of the high-pressure xenon arc was investigated by Baum and Dunkelman.[282] This source, operating under a pressure of approximately 20 atm, provides a particularly intense ultraviolet source. It was found that the radiance of the central spot exceeds that of the carbon crater by a factor of 23 at 2500 A, 12 at 3000 A, and 6 at 3500 A.

Carbon arcs have been the subject of further research, and have led to the development of a new high-intensity carbon arc lamp described by Gretener.[283] This device, called the Ventarc, produces an extremely high brilliance.

A power supply for the Western Union concentrated arc lamp was described by Mitchell,[284] and Buckingham[285] disclosed the new Western Union open-air concentrated arc lamp. This latter device, using molten zirconium, provides an intense light source of small size, relatively long life, and good stability.

T. Nuclear

With the advent of the new nuclear emulsions produced by Kodak here and

abroad, by Ilford in England and of special emulsions produced by individual investigators, considerable use is being made of photographic techniques in nuclear research. Much of the literature deals with the application of these techniques in such fields as cosmic ray, particle disintegration, particle energy and similar studies. Refinements in autoradiographic techniques have been reported and applications appear to be quite widespread. Work is continuing on the refinement of cloud chambers with a continuously sensitive cloud chamber being reported.[286] Characteristics of nuclear photographic emulsions, the techniques in which they are used, and the means for studying the results were subjects for a number of papers. (See Section **O** above.)

One unusual application concerned itself with the study of bird flight.[287] An apparatus measuring 8 mm by 5 mm, is attached to a bird. The device consists of a tube containing an annulus with a source of alpha particles at one end, a piece of photographic emulsion at the other, and a steel ball between. This device is established in such a manner that when the bird is in flight, there is a clear passage between the alpha-particle source and the emulsion, and when not in flight, the path of the alpha particles is blocked by the ball. Data on flying time may be deduced from photometric measurements of the emulsion.

U. Miscellaneous

A new apparatus permitting simultaneous and instantaneous photography of a 360° panorama was described by Blet[288] in France. Two silvered cones are oriented axially with the apexes facing. The image is reflected by the upper cone to the second cone and thence to a strip of 35-mm film held in a glass cylinder arranged about the second cone. In the image produced, the ordinates are amplified relative to the abscissas which proves advantageous in applications for which the device was designed, such as the measurement of sunlight variations with hour of day and season.

A device for automatic exposure control designed for the U.S. Air Force was disclosed by Bruck, Higgins and Ward[289] of Specialties, Inc. The control system consists of an additional lens and a photocell whose output is amplified to drive a servomotor geared to the camera-lens aperture. The device has a rapid response and is said to be particularly useful for aerial photography.

Photographic methods for production of optical gratings and reticles have been proven of considerable use. Two good survey papers were presented in 1950 by Leistner[290] and by Gundlach and Rzymkowski.[291]

The Ansco-Sweet-MacBeth color densitometer introduced earlier was described in this Society's JOURNAL by its designer,[292] while Morrison and Hoadley[293] of the Kodak Research Laboratory disclosed their spectrosensitometer. This latter device is designed to expose photographic materials through the range of 3500 and 9500 A for the evaluation of spectral sensitometry. The sensitometric steps are produced with repetitive increments of radiation level of log 0.3.

A qualitative technique for rendering lines of magnetic force visible was introduced.[294] The pole pieces of a magnet are covered with a suitable insulating material containing a few holes or slits. They are connected to each other by a tube containing an anode and cathode necessary for electrical gas discharge, which, under suitable pressures, becomes visible along the lines of force originating from the uncovered points on the surfaces of the pole pieces.

Another qualitative technique, this one making ultrasonic waves optically visible, was devised in Germany by Schreiber and Degner.[295] A ZnS–CdS phosphor is used of unknown phosphor content. After exposure to light for intervals between 30 sec and 5 min, the resulting phosphorescence is extinguished at the areas of maximum absorption of ultra-

sonic energy. Using a quartz transmitter of 1.56 mc/sec, satisfactory photographs were obtained at quartz-to-phosphor distances of 0.4 to 11 cm. Similar work was reported by Eckardt and Lindig,[296] also of Germany. They used a vessel containing air-free water closed by a celluloid film covered with a phosphor on its upper surface and placed 6 to 12 cm below a quartz transmitter operating at 70 w and 1.42 mc/sec. The phosphor is first illuminated by an arc lamp fitted with a quartz condenser for about 1 min. About $\frac{1}{2}$ min after the illumination is turned off, the quartz ultrasonic transmitter is energized, and the phosphor glows producing a sound picture which is photographed. When the transmitter is shut off, a negative sound picture is produced. Those parts of the phosphor which glowed previously, now appear as dark zones.

Phosphors are used for temperature field measurements in a method developed by Urbach and others at the Eastman Kodak Laboratories, Rochester, and described previous to 1950. Temperature-sensitive phosphors reveal as dark areas localized small increases in temperature when the phosphors are illuminated by ultraviolet light. Two techniques may be employed: one in which the phosphor is in contact with the body under study, and the second in which an image of the body is formed on a thin sheet of phosphor by reflection of the heat radiation from the body. It is said that accurate temperature distribution maps may be produced by photographic photometry from photographs produced in this manner. A review paper on the subject was presented by Urbach.[297]

An interesting apparatus permitting time-resolved spectroscopy of single sparks and other short-duration light sources was described by Gordon and Cady.[298] A Bausch & Lomb Medium Quartz Spectrograph was modified to permit sweeping the image of a selected region of the light source along the length of the slit by means of a rotating mirror operated at speeds to 36,000 rpm. The time base may be made as short as 10 μsec and time resolution of events in the source as brief as 0.5 μsec. Exploding wire and spark spectra were studied by this method.

V. New Publications

A number of new or reconstituted publications of interest to photographic instrumentation appeared in 1950. *Photographic Science and Technique*, a quarterly technical supplement designated as *Section B* of the *Photographic Society of America Journal; Photographic Engineering*, another quarterly, the official journal of the Society of Photographic Engineers of Washington, D.C.; *Functional Photography*, a monthly publication originating in England; and *Photo-France*, a monthly journal of general photographic interest.

The German journal *Photo-Kino-Technik* has changed its name to *Photo-Technik und Wirtschaft.*

V. CONCLUSIONS

From the foregoing brief abstracting of the literature of interest to photographic instrumentation, it may be concluded that this information is appearing in an ever-increasing number of journals and that it is becoming more difficult to locate and utilize.

A considerable effort is being made in a number of fields, and the design, development and use of photographic instruments and techniques are expanding. High-speed still and motion picture photography, oscillography, data-recording photography, reduction of data instrumentation, schlieren techniques, high speed processing, microscopy, radiography and nuclear photographic techniques are being given considerable attention and much more work for the future is indicated.

Widespread dissemination of information in this field is not currently possible. Very often, the editors of the several technical journals, because of its highly specialized nature, must omit photographic instrumentation data. Rarely will applications papers devote any space to a discussion of the instrumentation involved. No continuing digesting (as contrasted with abstracting) is being done in English, and the French publication, *Science et Industries Photographiques*, which comes closest to what is needed, is limited in accessibility to workers in this country. This publication is concerned in large measure with a number of photographic fields other than photographic instrumentation — particularly chemistry and physics relating to photosensitive systems. Although a remarkable scope is covered, it being essentially the work of one man, L. P. Clerc, it cannot be exhaustive. M. Clerc has for many years brought forth, almost single-handed, this admirable work and the author hopes that continuing survey with greater emphasis in the field of photographic instrumentation patterned along the line so remarkably developed by M. Clerc, can one day be established in this country.

In addition to the scientific journals of the world, an untapped source of considerable magnitude of data in this field is to be found in the research reports of government agencies and of government-sponsored private research activities. Much important information concerning instrumentation in this and other fields has received only small dissemination because no mechanism has been set up to digest it and because of security restriction, often too stringent. It is hoped that at least the nonclassified information can be included in the digest advocated.

The Society of Motion Picture and Television Engineers, through its liaison with the other technical societies concerned, hopes to improve dissemination of photographic instrumentation information in a number of ways presently under investigation. Steps are being taken to explore the possibility of establishing the continuing survey proposed.

The outlook for photographic instrumentation for the future continues to be bright, with new and large-scale effort being made in many directions. The design and development of new instruments is being accomplished more and more by those skilled in the properties of the photographic medium, rather than by investigators in the several sciences who find photographic techniques of use in their work. This trend will lead to better instruments on the commercial market, and will help to extend the usefulness of these techniques.

VI. BIBLIOGRAPHY

1. C. E. K. Mees, *Theory of the Photographic Process*, Macmillan, New York, 1942.
2. D. Hoffleit, *Sky and Telescope, 9:* 207–10, July 1950.
3. E. Muybridge, *Animal Locomotion*, J. S. Lippencott, Philadelphia, 1888.
4. L. P. Clerc, Editor, *Science et Industries Photographiques*, France.
5. *Photographic Abstracts*, Royal Photographic Society of Great Britain.
6. *Monthly Abstract Bulletin* of the Kodak Research Laboratories, Rochester, N. Y.
7. *Ansco Abstracts*.
8. *Physics Abstracts*, issued monthly by the Institution Elec. Eng. (England) with the Physical Soc., Amer. Phys. Soc., and the AIEE.
9. A. M. Worthington, *A Study of Splashes*, Longmans, New York, 1908.
10. Conrady, et al, *Photography as a Scientific Implement*, Blackie & Sons, London, 1923.
11. C. Cranz, *Lehrbuch der Ballistik*, Band 3, Springer, Berlin, 1927.
12. L. Fink, *Photographische Messtechnik*, Oldenbourg, Munchen, 1940.

13. C. H. S. Tupholme, *Photography in Engineering*, Faber and Hyperion Press, London, 1945.
14. A. Magnan, *Premiers Essais de Cinématographie Ultrarapide*, Hermann et Cie, Paris, 1932.
15. A. Magnan, *Cinématographie jusqu'à 12,000 Vues per Second*, Hermann et Cie, Paris, 1932.
16. P. Fayolle and P. Naslin, *Photographie Instantanée et Cinématographie Ultrarapide*, Editions de la Revue d'Optique, Paris, 1950.
17. E. W. H. Selwyn, *Photography in Astronomy*, Eastman Kodak Co., New York, 1950.
18. H. K. Bourne, *Discharge Lamps for Photography and Projection*, Chapman, London, 1948.
19. R. J. Hercock, *The Photographic Recording of Cathode Ray Tube Traces*, Ilford Ltd., London, 1947.
20. C. F. Powell and G. P. S. Occhialini, *Nuclear Physics in Photographs*, Clarendon Press, Oxford, 1947.
21. H. Yagoda, *Radioactive Measurements with Nuclear Emulsions*, John Wiley & Sons, New York, 1949.
22. D. A. Spencer, Editor, *Progress in Photography, 1940–1950*, Focal Press, London and New York, 1951.
23. J. M. Bourot, *Chronophotographie des Champs Aerodynamiques*, Publications Scientifiques et Techniques du Ministre de L'Air, Paris, 1949.
24. P. Thevenard and G. Tassel, *Le Cinéma Scientifique Français*, La Jeune Parque, Paris, 1948.
25. O. Lacmann, *Die Photogrammetrie in ihrer Anwendung auf Nichttopographischen Gebieten*, S. H. Verlag, Leipzig, 1950.
26. "Low Cost 16-mm Camera for Rocket Photography," R. E. Mueser and T. F. Irvine, Jr., *J. Am. Rocket Soc.*, *82:* 119–25, Sept. 1950.
27. "2000 m.p.h. Timing Equipment," *Rev. Sci. Instr.*, *21:* 889, Oct. 1950.
28. "High-Speed Photography of Reflection-Lighted Objects in Transonic Wind Tunnel Testing," E. R. Hinz, C. A. Main and E. P. Muhl, *Jour. SMPTE*, *55:* 613–26, Dec. 1950.
29. "Hand-Held High-Speed Motion Picture Camera," B. Marcus, *Phot. Eng.*, *1:* 57, Apr. 1950.
30. "High-Speed Photography of Underwater Explosions," P. M. Fye, *Jour. SMPTE*, *55:* 414–24, Oct. 1950.
31. "Cinematographic Analysis of Rapid Movements," L. Bull, *Mesures*, *15:* 329–333, Aug. 1950.
32. "100,000,000-Frame-Per-Second Camera," M. Sultanoff, *Rev. Sci. Instr.*, *21:* 653, July 1950.
———, *Jour. SMPTE*, *55:* 158–166, Aug. 1950; see also "High-Speed Motion Pictures by Multiple-Aperture Focal-Plane Scanners," and "Improvements in High-Speed Motion Pictures by Multiple-Aperture Focal-Plane Scanners," F. E. Tuttle, *ibid.*, *53:* 451 and 462, Nov. 1949.
33. "Simple Device for Ultra-high-speed Photography," H. Bartels and B. Eiselt, *Optik*, p. 56, Jan. 1950.
34. "Multiple Kerr Cell Camera," A. M. Zarem and F. R. Marshall, *Rev. Sci. Instr.*, *21:* 514–19, June 1950.
35. "Kerr Cell Camera and Flash Illumination Unit for Ballistic Photography," H. F. Quinn, W. B. McKay and O. J. Bourque, *J. Appl. Phys.*, *21:* 995–1001, Oct. 1950.
36. "Operation and Photographic Characteristics of Kerr Cell Type Electro-Optical Shutter," A. E. J. Holtham and H. A. Prime, *Proc. Phys. Soc., London, B63, No. 368:* 561–72, Aug. 1950.
37. "A High-Speed Camera with Electronic Controls," R. B. Bowersox, Jet Propulsion Laboratory, California Institute of Technology. *Paper K-9*, American Physical Society, Dec. 1950.
38. "The Development of High-Speed Photography and the Electrically Controlled Camera Shutter," H. Windischbauer, *Phot. Korr.*, *85:* 100–104, Dec. 1950.
39. "Iconoscope Electro-Optical Shutter for High-Speed Photography," H. A. Prime and R. C. Turnock, *Rev. Sci. Instr.*, *20:* 830, Nov. 1949;
———, *Proc. Inst. Elec. Eng.(II)*, *97:* 793–96, Dec. 1950.
40. "A New Method for the Photographic Study of Fast Transient Phenomena," J. S. Courtney-Pratt, *Research*, *2, No. 6:* 287–94, June 1949.
41. "Simultaneous Photography of Self-Luminous and Non-Self-Luminous

Effects," J. S. Rinehart, *Rev. Sci. Instr.*, *21:* 939–940, Nov. 1950.
42. "The Formation of a Blast Wave by a Very Intense Explosion, II. The Atomic Explosion of 1945," G. Taylor, *Proc. Roy. Soc., London*, *A201:* 175–86, Mar. 1950.
43. "Photography and Study of Underwater Missiles," W. H. Christie, *PSA Journal*, *16B:* 55, Aug. 1950.
44. "Photography in the Rocket Test Program," C. H. Elmer, *Jour. SMPTE*, *54:* 140, Feb. 1950.
45. "Augmented Flames in Half-Open Tubes," M. W. Evans, M. D. Scheer, L. J. Schoen and E. L. Miller, *J. Appl. Phys.*, *21:* 44–8, Jan. 1950.
46. "Study of Crack Propagation Using High-Speed Motion Pictures," H. I. Fusfeld and J. C. Fader, *J. Appl. Phys.*, *21:* 261–2 (Letter to Ed.), March 1950.
47. "The Development and Deionization Time of Heavy-Current AC Arcs," J. S. Forrest, *Brit. J. Appl. Phys.*, *1:* 10–13, Jan. 1950.
48. "The Behavior of the Cathode Spot on an Undisturbed Liquid Surface of Low Work Function," K. D. Froome, *Proc. Phys. Soc., London*, *63B:* 377–85, June 1950.
49. "The Retrograde Motion of the Arc Cathode Spot" C. J. Gallagher *J. Appl. Phys.*, *21:* 768–71, Aug. 1950.
50. "The Analogy between Hydraulic Jumps in Liquids and Shock Waves in Gases," F. R. Gilmore, M. S. Plesset and H. E. Crossley, Jr., *J. Appl. Phys.*, *21:* 243–9, March 1950.
51. "The Virtual Mass of a Sphere Entering Water Vertically," A. May and J. C. Woodhull, *J. Appl. Phys.*, *21:* 1285–89, Dec. 1950.
52. "Cinematographic Recording of the Velocity of Arterial Blood Flow," J. M. Potter and D. A. McDonald, *Nature*, *166:* 596–7, Oct. 1950.
53. "The Impact of Raindrops on Fabrics," M. and G. Karrholm, *Textile Research J.*, *20:* 215, Apr. 1950.
54. "High - Speed Motion Pictures in Textile Research," D. K. Fisher and J. C. Burnett, *Textile Research J.*, *20:* 259–269, Apr. 1950.
55. "High-Speed Camera Registers Physical Reaction of Iron Making," *Steel*, *126:* 119, Mar. 1950.
56. "High-Speed Photography in Paper Mill Maintenance," W. H. Niemeyer, *Paper Trade J.*, *131:* 22, July 1950.
57. "High - Speed Motion Pictures Detect Defects in Design," L. G. Waller, *Machine Design*, *22:* 143–5, Dec. 1950.
58. "Four Cameras for Research in the Aeronautical Field," Jean St. Thomas, *Phot. Eng.*, *1:* 76–93, July 1950.
59. "A Technique for Taking Motion Pictures of Electron Microscope Images," L. E. Preuss and J. H. L. Watson, *J. Appl. Phys.*, *21:* 902–3, Sept. 1950.
60. "Motion Picture Studies of Electron Bombardment of Colloidal Crystals," J. H. L. Watson and L. E. Preuss, *J. Appl. Phys.*, *21:* 904–7, Sept. 1950.
61. "A Dust Electricity Analyzer," W. B. Kunkel and J. W. Hansen, *Rev. Sci. Instr.*, *21:* 308–14, Apr. 1950.
62. "The Static Electrification of Dust Particles on Dispersion into a Cloud," W. B. Kunkel, *J, Appl. Phys.*, *21:* 820–32, Aug. 1950.
63. "Charge Distribution in Coarse Aerosols as a Function of Time," W. B. Kunkel, *J. Appl. Phys.*, *21:* 833–37, Aug. 1950.
64. "Preliminary Report on High Altitude Photography," C. T. Holliday, *Phot. Eng.*, *1:* 16, Jan. 1950.
65. "Photographic Determination of the Orientation of a Rocket," L. W. Fraser and R. S. Ostrander, *Phot. Eng.*, *1:* 105, Oct. 1950.
66. "The Propagation of Flames in Tubes," P. J. Wheatley, *Fuel*, *29:* 80–3, Apr. 1950.
67. "The Field of Flow Near a Free-Burning Carbon Arc," W. Hagenah, *Z. Physik*, *128* (*No. 2*): 279–88, 1950.
68. "Method Analysis by Motion Pictures," W. A. Vogler and T. R. DuBois, *Advanced Management*, *15:* 5–7, Apr. 1950.
69. "New Pace Scale Aids Time Studies; Film Record of Known Levels of Performance," R. N. Lehrer, *Factory Management*, *108:* 86, Apr. 1950.
70. "Time-Motion Improvements Come Faster with Films: Corn Plant

Huskers," G. Nadler, *Food Inds.*, *22:* 601–2, Apr. 1950.
71. "Polaroid-Land Camera Modified for Oscilloscope Recording to Produce Prints One Minute After Exposure," E. Blutman, *Tele-Tech*, *9:* 72, Apr. 1950.
72. "Techniques of Photo-Recording," H. P. Mansberg, *A. B. DuMont Oscillographer*, *12:* 3–16, No. 2, Apr.–June 1950.
73. "Photographing Test Patterns," L. E. Garner, Jr., *Electronics*, *23:* 138, Feb. 1950.
74. "Improved Cathode Ray Photographs," N. Fulmer, *Electronics*, *23:* 86–7, Mar. 1950.
75. "Single Pulse Recording of Radar Displays—Photographic," L. C. Mansur, *Tele-Tech*, *9:* 30–3, Jan. 1950.
76. "Motion Picture Color Photography of Color Television Images," W. R. Fraser and G. J. Badgley, *Jour. SMPTE*, *54:* 735, June 1950.
77. "Radar Measurements of the Initial Growth of Thunderstorm Precipitation Cells," G. R. Hilst and G. P. MacDowell, *Bull. Am. Meteorological Soc. 31:* 95–9, Mar. 1950.
78. "A Photographic Method for Displacement/Time Recording," F. M. Bruce, *Brit. J. Appl. Phys.*, *1:* 291–3, Nov. 1950.
79. "Streak Photography," I. Vigness and R. C. Nowak, *J. Appl. Phys.*, *21:* 445–8, May 1950.
80. "High Efficiency Apparatus for Lightning Chronophotography," D. J. Malan, *Rev. d'optique*, (*thèor.-instrum.*), *29:* 513–23, Oct. 1950.
81. "Full Application of Motion Study," A. G. Shaw, *Engineer*, *189:* 388–9, Mar. 1950.
82. "Mechanism of Detonation," H. H. M. Pike, *Nature*, *165:* 214–16, Feb. 1950.
83. "The State of a Detonating Explosive and the Velocity of the Ejected Gases," C. H. Johansson, *Arkiv Fysik 1*, *Paper 29:* 563–7, 1950.
84. "A Discussion on Detonation: Some Characteristics of Detonation," W. M. Evans, *Proc. Roy. Soc.*, *London*, *A204:* 12–17, Nov. 1950.
85. "A Discussion on Detonation: Pressure Measurements in Detonating Gases," R. M. Davies, J. D. Owen and D. H. Edwards, D. E. Thomas, *Proc. Roy. Soc.*, *London*, *A204:* 17–19, Nov. 1950.
86. "A Discussion on Detonation: Two New Streak Cameras," C. A. Adams, *Proc. Roy. Soc.*, *London*, *A204:* 19–20, Nov. 1950.
87. "A Discussion on Detonation: A New Photographic Method for Studying Fast Transient Phenomena," J. S. Courtney-Pratt, *Proc. Roy. Soc.*, *London*, *A204:* 27–29, Nov. 1950.
88. "Voltage Gradients in Long Gaseous Spark Channels," J. B. Higham and J. M. Meek, *Proc. Phys. Soc.*, *London*, *63B:* 633–48, Sept. 1950.
89. "The Expansion of Gaseous Spark Channels," J. B. Higham and J. M. Meek, *Proc. Phys. Soc.*, *London*, *63B:* 649–61, Sept. 1950.
90. "Photographing Sound Waves," W. E. Kock and W. K. Harvey, *Bell Lab. Record*, *28:* 304–6, July 1950.
91. "Bell Laboratories Photographs the Patterns of Sound Waves," *Elec. Eng.*, *69:* 766, Aug. 1950.
92. "A New Automatic 35-mm Camera," *Functional Phot.*, *1:* 4, Mar. 1950.
93. "The Streamlines Swiss 'Euram' Camera," A. Gazda, *PSA Journal*, *16B:* 88, Nov. 1950.
94. "Data Recording Camera," *Rev. Sci. Instr.*, *21:* 1030, Dec. 1950.
95. "Electrically Controlled Camera," *Rev. Sci. Instr.*, *21:* 820, Sept. 1950.
96. "Synchronous Camera," *Rev. Sci. Instr.*, *21:* 268, Mar. 1950.
97. "Airborne Synchronized Motion Picture Camera Recording System," V. J. White and S. J. Horwitz, *Elec. Eng.*, *69:* 324–7, Apr. 1950.
98. "Infrared Photography with Electric-Flash," F. E. Barstow, *Jour. SMPTE*, *55:* 485–95, Nov. 1950.
99. "A Reprojection Method for Studying Cloudchamber Photographs," D. A. Bromley, and R. D. Bradfield, *Rev. Sci. Instr.*, *21:* 190 (Lab. Note), Feb. 1950.
100. "A Semi-Automatic Device for Analyzing Events in Nuclear Emulsions," M. Blau, R. Rudin and S. Lindenbaum, *Rev. Sci. Instr.*, *21:* 978, Dec. 1950.
101. "Remote Control Projector for the

Examination of Experimental Records on 35-mm Film," E. L. R. Webb, *Can. J. Research, 28f:* 315–23, Aug. 1950.
102. "A Description of an Automatic Data-Analyzing Machine," B. S. Benson, *Mech. Eng., 72:* 285–288, Apr. 1950.
103. "Thinking of Microfilm?" R. R. Shaw, *Phot. Eng., 1:* 37, Apr. 1950.
104. "Pressurized Ballistic Range at the NOL," L. P. Gieseler, *Jour. SMPTE, 55:* 53, July 1950.
105. "Instrumentation for Exterior Ballistic Research in Rocketry," L. M. Biberman, *Instruments, 23:* 184–6, Feb. 1950.
106. "Hypersonic Research Facilities at the Ames Laboratory," V. I. Stevens, *J. Appl. Phys., 21:* 1150–55, Nov. 1950.
107. "Shadowgrams of Spherical Missiles Entering Water at Supersonic Speeds," J. H. McMillen, R. L. Kramer and D. E. Almand, *J. Appl. Phys., 21:* 1341–2 (Letter to Ed.), Dec. 1950.
108. "Measurement of Normal Burning Velocities of Propane-Air Flames from Shadow Photographs," J. W. Andersen and R. S. Fein, *J. Chem. Phys. 18:* 441–3, Apr. 1950.
109. "Improved Schlieren Apparatus Employing Multiple Slit-Gratings," T. A. Mortensen, *Rev. Sci. Instr., 21:* 3–6, Jan. 1950.
110. "Sharp Focusing Schlieren System," W. S. Miller, Jr., A. Kantrowitz and R. L. Trimpi, *J. Aeronaut. Sci., 17:* 311–14, May 1950.
111. "Studies With an Aerodynamically Instrumented Shock Tube," A. Hertzberg and A. Kantrowitz, *J. Appl. Phys., 21:* 874–878, Sept. 1950.
112. "Optical Bench for Investigations in the Supersonic Flow at Bellevue," E. Brun, H. Gondet and M. Plan, *J. Rech. Cent. Nat. Rech. Sci., 11:* 107–11, 1950.
113. "Results of Recent Hypersonic and Unsteady Flow Research at the Langley Aeronautical Laboratory," J. V. Becker, *J. Appl. Phys., 21:* 619, July 1950.
114. "Preliminary Investigation of the Use of Afterglow for Visualizing Low Density Compressible Flows," T. W. Williams and J. M. Benson, *NACA RM 19A24a*, Feb. 15, 1949.
115. "Reactions Between Nitrogen Dioxide and Formaldehyde. III. The Determination of Flame Speeds," F. H. Pollnard and R. M. H. Wyatt, *Trans. Faraday Soc., 46:* 281–9, Apr. 1950.
116. "The Temperature Field of a Free-Burning Carbon Arc," J. Sperling, *Z. Physik, 128 (No. 2)*: 269–78, 1950.
117. "Experimental and Theoretical Investigation of the Formation of Images of Non-Absorbing Objects," H. Wolter, *Ann. Physik, Leipzig, 7 Nos. 1–2:* 33–53, 1950.
118. "The Image of Cylindrical Phase Objects of Elliptical Cross-Section," H. Wolter, *Ann. Physik, Leipzig, 7, Nos. 3–4:* 147–56, Apr. 1950.
119. "Improvements to the Image in a Schlieren System by Means of the Minimum Light Condition," H. Wolter, *Ann. Physik, Leipzig, 7, Nos. 3–4:* 182–192, Apr. 1950.
120. "Two-Dimensional Color Schlieren Apparatus," H. Wolter, *Ann. Physik, Leipzig, 8, Nos. 1–2:* 1–10, July 1950.
121. "A Colour-Schlieren Apparatus," D. W. Holder and R. J. North, Report of National Physical Laboratory, Teddington, England, *Report 12,856, F.M. 1405.*
122. "A Quantitative Schlieren Apparatus without Photometry," J. Euler and W. Huppner, *Optik, 6, No. 6:* 332–6, 1950.
123. "Multiple Beam Interferometry," S. Tolansky, *Endeavour, 9:* 196–202, Oct. 1950.
124. "The Thickness Measurement of Thin Films by Multiple Beam Interferometry," G. D. Scott, T. A. McLauchlan and R. S. Sennett, *J. Appl. Phys., 21:* 843–6, Sept. 1950.
125. "Accurate Thickness Measurements with a Fabry-Perot Interferometer," L. G. Schulz, *J. Opt. Soc. Am., 40:* 177 (Letter to Ed.), Mar. 1950.
126. "The Spatial Photographic Recording of Fine Interference Phenomena," R. N. Wolf and F. C. Eisen, *J. Opt. Soc. Am., 40:* 143–6, Mar. 1950.
127. "An Interferometric Method for Accurate Thickness Measurements of Thin Evaporated Films," L. G.

Schulz, *J. Opt. Soc. Am., 40:* 690, Oct. 1950.

128. "A Diffraction Grating Interferometer," R. Kraushaar, *J. Opt. Soc. Am., 40:* 480 (Letter to Ed.), July 1950.
129. "Determination of Residual Stresses of Quenching Origin in Solid and Concentric Hollow Cylinders from Interferometric Observations," A. W. Saenz, *J. Appl. Phys., 21:* 962–5, Oct. 1950.
130. "A Simple Interferometric Test for Conical Flow," J. H. Giese, F. D. Bennett and V. E. Bergdolt, *J. Appl. Phys., 21:* 1226–31, Dec. 1950.
131. "Gibbs Photodont," *Jour. SMPTE, 54:* 765, June 1950.
132. "Simplified Body Cavity Camera," A. P. Neyhart, *Jour. SMPTE, 54:* 747–53, June 1950.
133. "A Semi-Automatic Aseptic Surgical Camera," L. A. Julin, *J. Biol. Phot. Assoc., 18:* 163, Nov. 1950.
134. "Kamm Stand for Medical Photography," P. Hansell, *J. Biol. Phot. Assoc., 18, No. 1:* 6, Feb. 1950.
135. "Photogrammetric Techniques as Applied to Medical Photography," E. A. Miskin, *Brit. J. Phot., 97:* 551–3, Oct. 1950.
136. "Clinical Aspects of Infrared Photography," K. Bowes, *Phot. J., 90B:* 63, May–June 1950.
137. "Microscope Optics," L. V. Foster, *J. Opt. Soc. Am., 40:* 269, May 1950.
138. "Versatile Photo-Micrographic Apparatus," *Rev. Sci. Instr., 21:* 676, July 1950.
139. "Metallograph," *Rev. Sci. Instr., 21:* 1030, Dec. 1950.
140. "Microscope Imagery and Interpretations," H. Osterberg, *J. Opt. Soc. Am., 40*: 295–303, May 1950.
141. "Photomicrography with the Concentrated-Arc Lamp," Julius Weber, *J. Biol. Phot. Assoc., 18:* 127, Aug. 1950.
142. "Preparation of Micrographs of Metals and Alloys; Data Sheets," *Foundry, 77:* 115–116, Nov. 1949; 133–4, Dec. 1949; 125–6, Jan. 1950; 195–6, Feb. 1950.
143. "Dental Microscopy and its Photography," E. R. Brain, *Phot. J., 90B:* 122, Sept.–Oct. 1950.
144. "On the Crazing of Linear High Polymers," C. C. Hsiao and J. A. Sauer, *J. Appl. Phys., 21:* 1071–1083, Nov. 1950.
145. "Microscopic Observations of the Solidification of Small Metal Droplets," D. Turnbull and R. E. Cech, *J. Appl. Phys., 21:* 804–10, Aug. 1950.
146. "A High-Low Temperature Microscope Stage," R. E. Cech, *Rev. Sci. Instr., 21:* 747–9, Aug. 1950.
147. "Surface Tension Effects in Oriented Thin Silver Films," G. W. Johnson, *J. Appl. Phys., 21:* 449–53, May 1950.
148. "Photomicrography with the Phase Microscope," O. W. Richards, *PSA Journal, 16B:* 94, Nov. 1950.
149. "Phase Contrast Microscopy for Opaque Specimens," J. R. Benford and R. L. Seidenberg, *J. Opt. Soc. Am., 40:* 314, May 1950.
150. "Color Phase-Contrast Microscopy: Requirements and Applications," C. P. Saylor, A. T. Brice and F. Zernike, *J. Opt. Soc. Am., 40:* 329, May 1950.
151. "A Phase Contrast Apparatus, Independent of the Microscope, Using a Phase Plate of Variable Absorption," M. Francon and G. Nomarski, *Compt. rend. acad. sci., Paris, 230:* 1050–1, Mar. 1950.
152. "Phase Plate with Variable Contrast by Reflection," M. Francon and G. Nomarski, *Compt. rend. acad. sci., Paris, 230:* 1392–4, Apr. 1950.
153. "A New Series of Microscope Objectives. III. Ultra-Violet Objectives of Intermediate Numerical Aperture," D. S. Grey, *J. Opt. Soc. Am., 40:* 283, May 1950.
154. "Dr. E. H. Land's Colour Translating Microscope," W. F. Berg, *Phot. J., 90B:* 98, July–Aug. 1950.
155. "Reflecting Microscope," R. C. Mellors, *Science, 112:* 381–9, Oct. 1950.
156. "An Apparatus for Ultra-Violet Microscopy of Living Cells," H. G. Davies and P. M. B. Walker, *Phot. J., 90B:* 92, July–Aug. 1950.
157. "Ultra-Violet Microscopy of Tumour and Virus of Rouse Fowl Sarcoma," E. M. F. Roe and R. G. King, *Phot. J., 90B:* 94, July–Aug. 1950.
158. "Ultra-Violet Photography of Hot Metal Surfaces," G. A. Jones, *Phot. J., 90B:* 99, July–Aug. 1950.

159. "The Philips 100 k.v. Electron Microscope," A. C. VanDorsten, H. Nieuwdorp and A. Verhoeff, *Philips Tech. Rev., 12:* 33–50, Aug. 1950.
160. "Electron Microscope," *Rev. Sci Instr., 21:* 576, June 1950.
161. "A Small Electron Microscope," J. A. Reisener and E. G. Darnfeld, *J. Appl. Phys., 21:* 1131–39, Nov. 1950.
162. "Three-Stage Electron Microscope with Stereographic Dark Field, and Electron Diffraction Capabilities," M. E. Haine, R. S. Page and R. G. Garfitt, *J. Appl. Phys., 21:* 173–182, Feb. 1950.
163. "Rendering Visible Single Atoms and Molecules in the Field Electron Microscope," E. W. Muller, *Z. Naturforsch., 5a:* 473–9, Sept. 1950.
164. "Electrons vs. Photons—A Comparison of Microscopes," L. Marton, *J. Opt. Soc. Am., 40:* 269, May 1950.
165. "Laboratory Modifications in the RCA Model EMC Electron Microscope," S. G. Ellis, *Rev. Sci. Instr., 21:* 255, Mar. 1950.
166. "Molecular Diffraction Attachment for the RCA Microscope," B. O. Heston and P. R. Cutter, *Rev. Sci. Instr., 21:* 608, July 1950.
167. "Modification of Electron Microscope for Electron Optical Shadow Method," J. A. Simpson and A. Van Bronkhorst, *Rev. Sci. Instr., 21:* 669, July 1950.
168. "Lapping Technique: To Improve the Image Quality of Electron Microscope Lenses," F. A. Hamm, *J. Appl. Phys., 21:* 278–83, Apr. 1950.
169. "Vibration Studies; Related to Electron Microscopy," F. A. Hamm and F. C. Snowden, *Rev. Sci. Instr., 21:* 426, May 1950.
170. "Removable Intermediate Lens for Extending the Magnification Range of an Electron Microscope," J. Hillier, *J. Appl. Phys., 21:* 785–90, Aug. 1950.
171. "Electron-Microradiography of Electro Deposited Metals," R. Weil and H. J. Read, *J. Appl. Phys., 21:* 1068 (Letter to Ed.), Oct. 1950.
172. "Aluminum Oxide Replicas for Electron Microscopy Produced by a Two Step Process," G. Hass and M. E. McFarland, *J. Appl. Phys., 21:* 435–6, May 1950.
173. "Improved Ultra-Thin Sectioning of Tissue for Electron Microscopy," J. Hillier and M. E. Gettner, *J. Appl. Phys., 21:* 889–95, Sept. 1950.
174. "Metallic Evaporation and the Diameter of Tobacco Mosaic Virus with the Electron Microscope," H. Kahler and B. J. Lloyd, Jr., *J. Appl. Phys., 21:* 699–704, July 1950.
175. "The Apparent Size of Objects as Observed in the Electron Microscope," S. F. Kern and R. A. Kern, *J. Appl. Phys., 21:* 705–7, July 1950.
176. "Comments on the Use of Latex Spheres as Size Standards in Electron Microscopy," C. H. Gerould, *J. Appl. Phys., 21:* 183–4 (Letter to Ed.), Feb. 1950.
177. "Use of Spraying Methods and of Volatile Suspending Media in the Preparation of Specimens for Electron Microscopy," R. C. Backus and R. C. Williams, *J. Appl. Phys., 21:* 11 (*ff.*), Jan. 1950.
178. "Electron Microscopy of Wet Biological Tissues by Replica Techniques," I. W. Fischbein, *J. Appl. Phys., 21:* 1199–1214, Dec. 1950.
179. "Use of Critical Point Phenomena in Preparing Specimens for the Electron Microscope," T. F. Anderson, *J. Appl. Phys., 21:* 724 (Letter to Ed.), July 1950.
180. "Low Temperature Replica Method for Electron Microscopy," C. E. Hall, *J. Appl. Phys., 21:* 61 (Letter to Ed.), Jan. 1950.
181. "X-Ray Microscope," *Instruments, 23:* 840, Aug. 1950.
182. "Resolving Power of an X-Ray Microscope," E. Prince, *J. Appl. Phys., 21:* 698, July 1950.
183. "An Approach to X-Ray Microscopy," P. Kirkpatrick, *Nature, 166:* 251–3, August 12, 1950.
184. "Wave-Lengths Suitable for X-Ray Microscopy of Biological Specimens," J. L. Farrant, *J. Appl. Phys., 21:* 63 (Letter to Ed.), Jan. 1950.
185. "Exposure Meter for Photomicrography," *Electronics, 23:* 123, Jan. 1950.
186. "Generalized Microscopy and the Two Wave Length Microscope," M.

J. Buerger, *J. Appl. Phys., 21:* 909–917, Sept. 1950.
187. "The Photography of Atoms in Crystals," M. J. Buerger, *Proc. Nat. Acad. Sci., Wash., 36:* 330–5, May 1950.
188. "An Observation Chamber for Ultramicroscopic Investigations on Aerosols," O. E. Schweckendiek, *Z. Naturforsch., 5a:* 153–6, Mar. 1950.
189. "Microspectroscopy," J. R. Loofbourow, *J. Opt. Soc. Am., 40:* 317–25, May 1950.
190. "Infra-Red Microspectroscopy," E. R. Blout, G. R. Bird and D. S. Grey, *J. Opt. Soc. Am., 40:* 304–13, May 1950.
191. "Recent Developments in Medical Photography and Radiography," W. Watson, *Phot. J., 90B:* 72, May–June 1950.
192. "A New X-Ray Camera," S. W. Bowler, *Brit. J. Phot., 97:* 364–5, July 1950.
193. "New Trends in Radiographic Screening Techniques Utilizing Schmidt Optical Systems and High-Speed Development," R. H. Morgan, *Radiology, 55:* 97–100, July 1950.
194. "The Intensification of the Fluorescent Image in Radiology," F. I. G. Rawlins, *Brit. J. Radiology, 28:* 460–4, Aug. 1950.
195. "Amplifying and Intensifying the Fluoroscopic Image by Means of a Scanning X-Ray Tube," R. J. Moon, *Science, 112:* 389–95, Oct. 1950.
196. "Speed and Contrast in Radiography," H. S. Tasker, *Phot. J., 90B:* 9–21, Jan.–Feb. 1950.
197. "X-Ray vs. Light," H. S. Tasker, *Phot. J., 90B:* 58, May–June 1950.
198. "Megavolt Radiography," R. Meakin, *Phot. J., 90B:* 100, July–Aug. 1950.
199. "The Calculation of Vowel Resonances and an Electrical Vocal Tract," H. K. Dunn, *J. Acoust. Soc. Am., 22:* 740–53, Nov. 1950.
200. "Kineradiography," J. A. Campbell, *Radiology, 54:* 559, Apr. 1950.
201. "Use of the Cine Fluorographic Method for Tracking Purposes," L. Reynolds, K. E. Corrigan and H. S. Haden, *Am. J. Roentgenol., 63:* 902–14, June 1950.
202. "Kineradiography," R. J. Reynolds, *Phot. J., 90B:* 99, July–Aug. 1950.
203. "Angiocardio Cinematography," R. Janker, *Am. J. Roentgenol., 64:* 904, Nov. 1950.
204. "High Voltage Equipment for Cineradiography," *Engineer, 190:* 186–7, Aug. 1950.
205. "New Cineradiographic Apparatus," *Elec. Eng., 22:* 369–70, Sept. 1950.
206. "Clinical Cine-Fluorography," R. F. Rushmer, R. S. Bark and J. A. Hendron, *Radiology, 55:* 588–92, Oct. 1950.
207. "Electronically Controlled Cineradiographic Apparatus," V. Quittner, *Elec. Eng., 22:* 363–8, Sept. 1950.
208. "Flash Radiography," G. C. Pollitt, *Phot. J., 90B:* 104, July–Aug. 1950.
209. "Recent Progress in Flash Radiography," J. C. Clark, *Papers on Radiography*, ASTM 1950.
210. "On the Working Process of Impulse X-Ray Tubes," E. Funfer, *Z. angew. Phys., 2, No. 1:* 25–33, 1950.
211. "A Million-Volt Resonant Cavity X-Ray Tube," B. Y. Mills, *Proc. Inst. Elec. Eng., Pt. III, 97:* 425–37, Nov. 1950.
212. "The Equation of State of Water at High Pressures, from X-Ray Flash Photographs of Intense Shock Waves," R. Schall, *Z. angew. Phys., 2, No. 6:* 252–4, 1950.
213. "Use of Radioactive Isotopes in Industrial Radiography," G. H. Tenney, *Non-Destructive Testing, 8:* 6–8, Autumn 1950.
214. "Image Formation by Means of X-Rays," Y. Cauchois, *Rev. d'optique, théor.-instr., 29:* 151–63, Mar. 1950.
215. "Chemical Analysis by Means of X-Rays. IV. A Quantitative Analytical Method Using a Standard Density," L. R. Alvarez, *An. Real Soc. Esp. Fis. y Quin., 46A:* 77–82, Mar.–Apr. 1950.
216. "X-Ray Tube Producing a Beam of X-Rays Convergent to a Point," C. H. Bachman and S. J. Silverman, *J. Appl. Phys., 21:* 615 (Letters to Ed.), June 1950.
217. "Light Energy and Spectral Distribution for Some Important X-Ray Screens," H. Skoldborn, *J. Appl. Phys., 21:* 546–52, June 1950.

218. "Quantum Efficiency in Photographic X-Ray Exposures," D. Bromley and R. H. Herz, *Proc. Phys. Soc., London*, *B*, *63:* 90–106, Feb. 1950.
219. "Photography Under the Sea," W. D. Chesterman, *Functional Photography, 1:* 5–8, May. 1950.
220. "Underwater Photography," P. Bucher, *Photo-France, 1:* 6–10, Aug. 1950.
221. "Experimental Underwater Camera and Illuminator," M. S. Jenner, *Phot. Eng., 1:* 139, Oct. 1950.
222. "Photography and Deep Water," B. Ulrich, *Foto-Kino-Technik, 4:* 187, June 1950.
223. "Some Aspects of Deep Sea Underwater Photography," J. Hahn, *PSA Journal, 16B:* 27, June 1950.
224. "Underwater Photography," J. B. Collins, *Phot. J., 90B:* 24, Jan.–Feb. 1950.
225. "U. S. Naval Underwater Cinematography Techniques," R. R. Conger, *Jour. SMPTE, 55:* 627–34, Dec. 1950.
226. *Photo Developments, 29:* 40, June 1950.
227. "Photo Materials for Use in the Ultra-Violet," R. D. B. Fraser, *J. Sci. Instr., 27:* 106–7, Apr. 1950.
228. "Photographing Spectra in the Vacuum UV," A. L. Schoen, E. S. Hodge, *J. Opt. Soc. Am., 40:* 23–8, Jan. 1950.
229. "Polaroid-Land Film," E. H. Land, *Phot. J., 90:* 7, 1950.
230. *Rev. Sci. Instr., 21:* 506, May 1950.
231. "A New Photographic Material—A High Resolution Emulsion for Autoradiography," R. W. Berriman, R. H. Herz and G. W. W. Stevens, *Brit. J. Radiology, 23:* 472–7, Aug. 1950.
232. "Continuous Method of Preparation of Photographic Emulsions Specially Sensitive to Ionizing Particles," P. Demers, *Compt. rend. acad. sci., Paris, 231:* 616–617, Sept. 1950.
233. "Spectral Sensitivity of Two Commercial X-Ray Films between 0.2 and 2.5 Angstroms," H. E. Seemann, *Rev. Sci. Instr., 21:* 314, Apr. 1950.
234. "Latensification Studies with Ozone," W. Vanselow, E. K. Colton and E. J. Wiegand, *PSA Journal, 16B:* 97, Nov. 1950.
235. "Gold Sensitization of X-Ray Films," H. Hoerlin, and F. W. H. Mueller, *J. Opt. Soc. Am., 41:* 246–51, Apr. 1950.
236. "Some Methods of Treating an Under-Exposed Negative," H. Hartridge, *Phot. J., 90B:* 41, Mar.–Apr. 1950.
237. "Combined Effect of Infrared Radiation and Intensification Upon the Photographic Latent Image," L. Fortmiller, T. H. James, R. F. Quirk and W. Vanselow, *J. Opt. Soc. Am., 40:* 487–96, Aug. 1950.
238. "6-Nitrobenzimidazole and Benzatriazole as Antifoggants," J. A. Schantz, *Phot. Eng., 1:* 63, Apr. 1950.
239. "Ion Exchange and the Reclamation of Photographic Wash Water," S. Levinos, *Phot. Eng., 1:* 69, July 1950.
240. "Double Development of Nuclear Emulsions," C. Jech, *Phys. Rev., 80:* 759–60, Nov. 1950.
241. "Temperature Coefficient of Swelling and Development in Thick Emulsions for Nuclear Research," G. W. W. Stevens, *Phot. J., 90B:* 129, Sept.–Oct. 1950.
242. "Photographic Reciprocity Law Failure and Related Effects; the Low Intensity Failure," E. Katz, *J. Chem. Phys., 17:* 1132–41, Nov. 1949.
243. "Photographic Reciprocity Law Failure and Related Effects: the Low Intensity Sequence Effect," E. Katz, *J. Chem. Phys., 18:* 499–506, Apr. 1950.
244. "Low Intensity Reciprocity Law Failure in Photographic Exposure: Energy Depth of Electron Traps in Latent-Image Formation; Number of Quanta Required to Form the Stable Sublatent Image," J. H. Webb, *J. Opt. Soc. Am., 40:* 3–13, Jan. 1950.
245. "Low Intensity Reciprocity-Law Failure in Photo Exposure: II. Multiple-Quantum Hits in a Critical Time Period," J. H. Webb, *J. Opt. Soc. Am., 40:* 197–202, Apr. 1950.
246. "A New Reciprocity Failure in Photographic Exposure at High Intensity," G. G. Milne, paper presented at *Optical Society Meeting*, Cleveland, Ohio, Oct. 1950.
247. "The Metal-Diazonium Process," C. J. Dippel, *Phot. J., 90B:* 34, Mar.–Apr. 1950.
248. "Metal Diazonium System for Photo

Reproductions," R. J. H. Alink, C. J. Dippel and K. J. Keuning, *Jour. SMPTE, 54:* 345–66, Mar. 1950.
249. "Xerography," *Phot. J., 90B:* 66, May–June 1950.
250. "Xeroradiography—A Basic Development in X-Ray Non-Destructive Testing," R. C. McMaster and R. M. Schaffert, *Non-Destructive Testing*, Summer 1950.
251. "A Survey of Photographic Processes and Materials," E. K. Kaprelian, *Phot. Eng., 1:* 42, Apr. 1950.
252. "A Self-Processing Camera for the Rapid Production of Photographic Negatives," E. W. Jackson, *Brit. J. Phot., 97:* 55, Feb. 1950.
253. "A Small Continuous Processing Machine for Experimental Work," G. I. P. Levensen, *J. Brit. Kinemat. Soc., 16:* 2–8, Jan. 1950.
254. "Machine for Rapidly Processing Photographic Trace Recordings," G. I. P. Levensen, *J. Sci. Instr., 27:* 170–1, June 1950.
255. "A 16-mm Rapid Film Processor," J. S. Hall, A. Mayer and G. Maslach, *Jour. SMPTE, 55:* 27–36, July 1950.
256. "Simplification of Motion Picture Processing Methods," C. E. Ives and C. J. Kunz, *Jour. SMPTE, 55:* 3, July 1950.
257. "High-Speed Processing of 35-mm Motion Pictures," C. M. Tuttle and F. M. Brown, *Jour. SMPTE, 54:* 149, Feb. 1950.
258. "Stabilization Processing," H. D. Russell, E. C. Yackel and S. S. Bruce, *PSA Journal, 16B:* 59, Aug. 1950.
259. "Rapid Drying of Photographic Material," I. Davies and A. K. Soper, *Brit. J. Phot., 97:* 268, May 1950.
260. "The Variable Focus Pan-Cinor Objective and its Applications," R. Cuvillier, *Science et inds. phot., 21:* 324, Sept. 1950.
261. "Wide Angle Underwater Lens," E. M. Thorndike, *J. Opt. Soc. Am., 40:* 823–4, Dec. 1950.
262. "Description of Wide Angle Schmidt Optical Systems," E. M. Wormser, *J. Opt. Soc. Am., 40:* 412–15, July 1950.
263. "The Progress of Wide Aperture Photographic Objectives," B. Seegert, *Z. wiss. Phot., 45, Nos. 4–6:* 95–118, 1950.
264. "Catadioptric Objectives," M. Paul, *Science et inds. phot., 21:* 81, Mar. 1950.
265. "The Tachonar, *F*/1 Objective," *Foto-Kino-Technik, 4:* 223, July 1950.
266. "The Construction of Interference Filters for the Transmission of Light of Specified Wavelengths," K. M. Greenland and C. Billington, *Proc. Phys. Soc., London, B, 63:* 359–63, May 1950.
267. "Calculation of Interference Filters," J. Roig, C. Descamps, *Compt. rend. acad. sci., Paris, 230:* 827–9, Feb. 1950.
268. "Interference Mirrors for Arc Projector," G. J. Koch, *Jour. SMPTE, 55:* 439, Oct. 1950.
269. "Electrical Color Filters," V. A. Babits, Jr. and H. F. Hicks, Jr., *Electronics, 23:* 112–15, Nov. 1950.
270. "A High-Intensity, Short-Duration Spark Light Source," J. A. Fitzpatrick, J. C. Hubbard and W. J. Thaler, *J. Appl. Phys., 21:* 1269–71, Dec. 1950.
271. "The Light Emission from High-Current Spark Discharges, I," G. Glaser, *Optik, 7, No. 1:* 33–53, 1950.
272. "The Light Emission from High-Current Spark Discharges, II," G. Glaser, *Optik, 7, No. 2:* 61–90, 1950.
273. "New Low-Voltage, Low-Power Flash Tube of High Efficiency," E. B. Noel and P. B. Davis, *PSA Journal, 16B:* 11, Jan. 1950.
274. "Stroboscope as a Light Source for Motion Pictures," R. S. Carlson and H. E. Edgerton, *Jour. SMPTE, 55:* 88–100, July 1950.
275. "Electrical and Radiation Characteristics of Flash Lamps," H. N. Olsen and W. S. Huxford, *Jour. SMPTE, 55:* 285, Sept. 1950.
276. "The Application of White Light Flash Tubes to Instantaneous Photomicrography in Ordinary or Phase Contrast Microscopy," M. Laporte, *Compt. rend. acad. sci., Paris, 230:* 1592–3, May 1950.
277. "Discharge Lamps for Projection and Cinematography," M. Laporte, *J. Phys., (8), 11:* 4–5, Dec. 1950.
278. "Intermittent Projection Light: A Possibility for the Future in Film

Projection," W. Hagemann, *Bild und Ton, 3:* 35–8, Feb. 1950.

279. "Cine-Flash; A New Lighting Equipment for High-Speed Cinematography and Studio Effects," H. K. Bourne and E. J. G. Beeson, *Jour. SMPTE, 55:* 229–312, Sept. 1950.
280. "New Instrument Aids in Photography of Air Flow," *Gen. Elec. Rev., 53:* 48–9, Oct. 1950.
281. "A Study of the Short-Duration, High-Intensity Electric Arc as a Source of Visible Light," G. D. Hoyt and W. W. McCormick, *J. Opt. Soc. Am., 40:* 658, Oct. 1950.
282. "Ultra-Violet Radiation of the High-Pressure Xenon Arc," W. A. Baum and L. Dunkelman, *J. Opt. Soc. Am., 40:* 782, Nov. 1950.
283. "Physical Principles, Design and Performance of the Ventarc High-Intensity Projection Lamps," E. Gretener, *Jour. SMPTE, 55:* 391–413, Oct. 1950.
284. "Power Supply for the Cenco Concentrated-Arc Lamp," J. M. Mitchell, *Rev. Sci. Instr., 21:* 497, May 1950.
285. "Open-Air Concentrated Arc Lamp," W. D. Buckingham, *Jour. SMPTE, 54:* 567–84, May 1950.
286. "A Continuously Sensitive Cloud Chamber," T. S. Needels and C. E. Nielsen, *Rev. Sci. Instr., 21:* 976, Dec. 1950.
287. "Flight Records: A Technique for the Study of Bird Navigation," D. H. Wilkinson, *Nature, 165:* 188, Feb. 1950.
288. "A New Apparatus for Integral Panorama Photography," G. Blet, *Science et inds. phot., 21:* 281, Aug. 1950.
289. "Automatic Exposure Control," G. Bruck, J. Higgins and J. Ward, *Electronics, 23:* 74–8, May 1950.
290. "Photographic Methods for Producing Reticles," C. Leistner, *Phot. Eng., 1:* 7, Jan. 1950.
291. "The Production of Optical Gratings by the Photographic Method," K. Gundlach, J. Rzymkowski, *Z. wiss. Phot., 45, Nos. 1–3:* 8–31, 1950.
292. "Color Densitometer," M. H. Sweet, *Jour. SMPTE, 54:* 35–62, Jan. 1950.
293. "A Spectrosensitometer," C. A. Morrison, H. O. Hoadley, *PSA Journal, 16B:* 64, Aug. 1950.
294. "A Method of Making Magnetic Lines of Force Visible," F. Blaha, *Z. Naturforsch., 5a:* 233–4, Apr. 1950.
295. "Method of Making Ultrasonic Waves Visible," H. Schreiber and W. Degner, *Naturwissenschaften, 37, No. 15:* 358–9, 1950.
296. "Illumination of Phosphors by Ultrasonic Waves," A. Eckardt and O. Lindig, *Ann. Physik, Leipzig, 7, Nos. 7–8:* 410–12, 1950.
297. "Thermography," F. Urbach, *Phot. J., 90B:* 109–14, July–Aug. 1950.
298. "An Apparatus for Time-Resolved Spectroscopy," G. Gordon and W. M. Cady, *J. Opt. Soc. Am., 40:* 852, Dec. 1950.
299. "Use of image phototube as a high-speed camera shutter," A. W. Hogan, *Jour. SMPTE*, vol. 56, pp. 635–641, June 1951.

Further Report on Screen Brightness Committee Theater Survey

By W. W. LOZIER, Committee Chairman

THE RESULTS of a survey by the Screen Brightness Committee in 125 indoor theaters and 18 West Coast studio 35-mm review rooms have recently been presented in this JOURNAL.[1] These included data on theater seating capacity, screen width, screen brightness, side and corner distribution and screen reflectivity.

The survey data included measurements of the incident illumination on the theater screen at the center, the two sides and at two diagonally opposite corners.[2] These data make possible an analysis of evenness of balance of illumination on the screen.

Side and Corner Unbalance on Individual Projectors

Figures 1 and 2 show the range of side and corner unbalance observed with the 251 projectors in the indoor theaters and with the 36 projectors in the 18 West Coast review rooms. Side unbalance is defined as the difference between the two side readings of intensity of illumination on the screen divided by their average, expressed as a percentage. The corner unbalance is similarly determined from the two corner readings for each projector. These unbalance values can also be expressed as the ratio of high to low value and this scale is shown at the tops of Figs. 1 and 2. These refer solely to the variations over the screen with individual projectors.

Figure 1 shows that a little less than one-third of the theater projectors had a side unbalance of 10% or less. Another third had 10% to 30% unbalance. About 18% of the projectors had an unbalance greater than 40%, which means one side was 50% or more higher in intensity than the other.

Figure 2 shows an even wider range of corner unbalance. One-quarter of the theater projectors had a 0 to 10% unbalance, over one-third had 10% to 30% unbalance and almost one-fifth were over 40% out of balance. Approximately 5% had over 70% corner unbalance, which means that one corner-intensity value was more than twice that of the other.

The data on the review rooms are in striking contrast to the indoor theaters and show almost two-thirds of the

---

Presented on October 19, 1951, at the Society's Convention at Hollywood, Calif., by W. W. Lozier, Committee Chairman, Carbon Products Service Dept., National Carbon Company, Division of Union Carbide and Carbon Corp., Fostoria, Ohio.

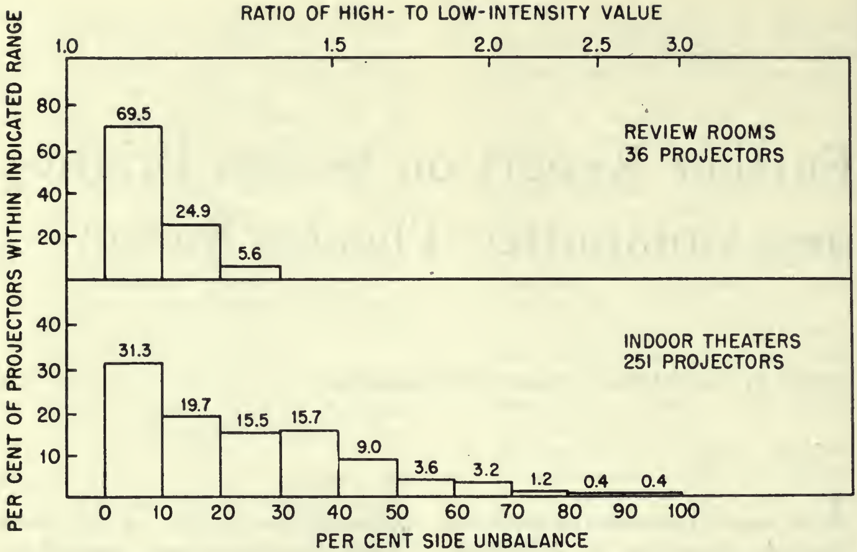


Fig. 1. Unbalance of intensity of illumination at sides of screen. Range obtained in the survey refers to side-to-side difference on the screen with the same projector.

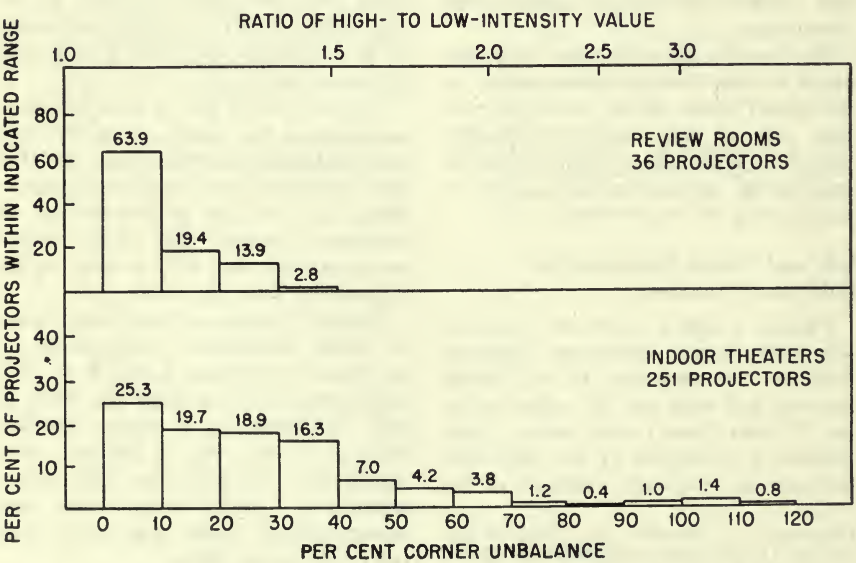


Fig. 2. Unbalance of intensity of illumination at corners of screen. Range obtained in the survey refers to corner-to-corner difference on the screen with the same projector.

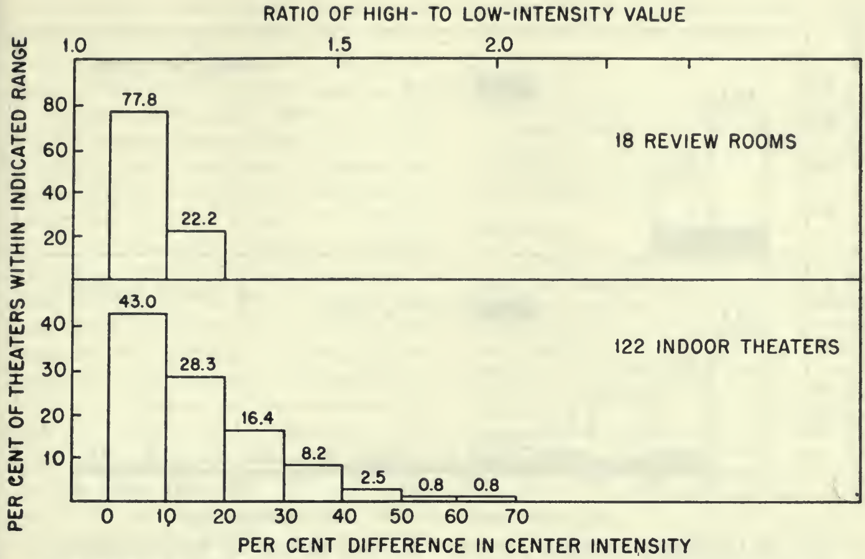


Fig. 3. Difference between projectors in each theater in intensity of illumination at center of screen. Range obtained measures change observable at change-over.

projectors to have less than 10% side and corner unbalance. This better review-room performance will be evident in the further comparisons to be shown.

Comparison Between Projectors in Each Theater

The percentage difference in intensity of illumination at the center of the screen has been determined for the two projectors in each theater. (The maximum difference was used in cases where there were more than two projectors in a single theater.) This, then, is a measure of the change in illumination at the center of the screen at the time of a change-over. The distribution of such center-of-screen differences for 122 indoor theaters is given in Fig. 3.

About 40% of the theaters had a difference of 0 to 10% in center-of-screen intensities for their projectors. A little over one-quarter of the theaters had a change of over 20%. More than three-quarters of the review rooms show less than 10% difference in intensity between projectors at the center of the screen.

In addition to the changes in intensity at the center of the screen, at the time of a change-over, changes in unbalance of illumination on the screen may also be observable. Figures 4 and 5 show how the side and corner unbalance differed between the two (or more) projectors in the 122 theaters. Two factors contribute to a change in unbalance of sides and corners. One of these is the change in magnitude of unbalance in going from one projector to the other, and the other factor is a change in direction of the unbalance. For example, if the side of higher intensity is on one side of the screen with one projector and on the other side of the other screen with the other projector, then this would produce a noticeable shift of unbalance at a change-over even though the magnitude of unbalance were the same in both cases. This was measured by combining the numerical magnitude of unbalance in such cases and these theaters are represented by the shaded portions of Figs. 4 and 5. Approximately one-quarter

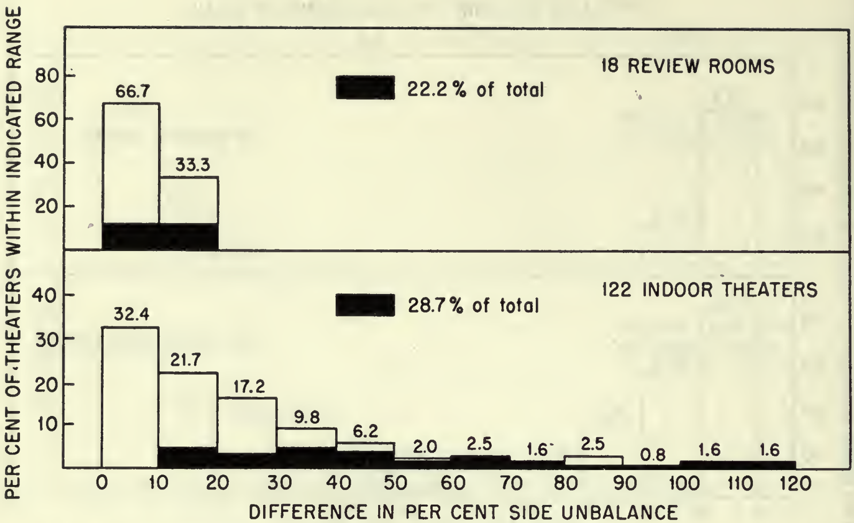


Fig. 4. Difference between projectors in each theater in side unbalance. Range obtained in the survey measures change observable at change-over.

Note: The shaded portion represents those theaters in which the side of higher intensity is oppositely positioned on the screen for the two projectors of the same theater.

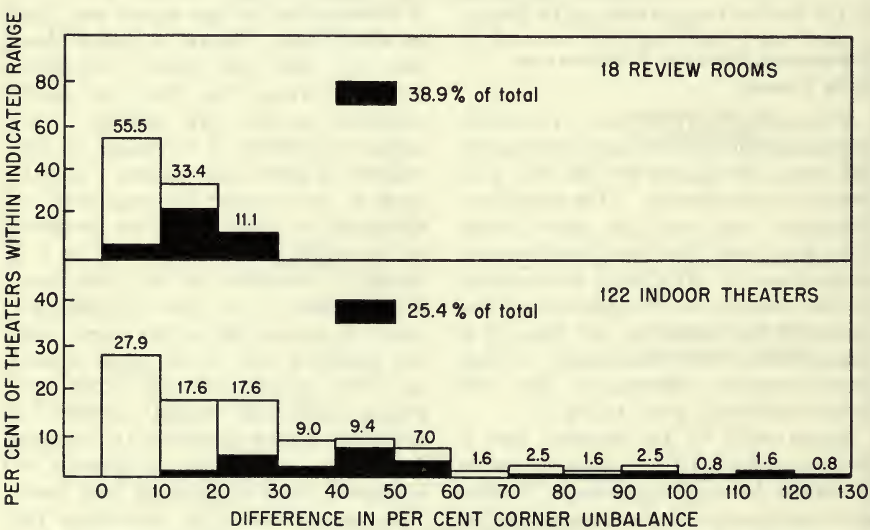


Fig. 5. Difference between projectors in each theater in corner unbalance. Range obtained in the survey measures change observable at change-over.

Note: The shaded portion represents those theaters in which the corner of higher intensity is oppositely positioned on the screen for the two projectors of the same theater.

to one-third of the indoor theaters and review rooms experienced such changes in position of side and corner of highest intensity at the change-over.

Figure 4 shows that about one-third of the theaters experienced a 0 to 10% change in side unbalance. Almost half experienced a change in unbalance of more than 20%. Figure 5 indicates that the change in corner unbalance runs slightly greater than the change in side unbalance. It is to be noted that the large changes in unbalance are contributed primarily by the shaded portions and represent, therefore, a change in position on the screen of the side or corner of higher intensity. The change of unbalance of the review rooms is much less than that of the theaters, as would be expected from the smaller unbalance of the individual review-room projectors as shown in Figs. 1 and 2.

Summary

These data have indicated that many theater screens are illuminated in a noticeably and in some cases objectionably unbalanced manner considering both individual projectors and also change-overs between projectors. The much better balance of the review-room screens is believed to indicate the practicability of theater improvement. Many factors can probably contribute to such improvement, ranging all the way from installation of better designed equipment in some cases to simply better adjustment and operation of existing equipment in other cases.

The Screen Brightness Committee recognizes a primary responsibility in setting up workable recommended practices regarding intensity and distribution of screen illumination which will insure effective projection of motion pictures. However, until these are formulated, many of the undesirable situations can be greatly improved by better attention to the details of operation and maintenance of existing equipment.

References

1. W. W. Lozier, Chairman, "Report on Screen Brightness Committee Theater Survey," *Jour. SMPTE*, vol. 57, pp. 238–246, Sept. 1951.
2. Reference 1, Fig. 1.

Discussion

E. R. Geib: I believe that this committee should be complimented for the work done so far, as these facts will be very beneficial to the industry. Now, I would like to ask one question. I think he has partially answered it already, and that is I assume that the intention of the committee is to continue the work by establishing a standard of uniformity of light from side-to-center, from corner-to-corner, and also the ratio of the light from side-to-center.

W. W. Lozier: Those are two of our active projects. We haven't anything to report on them yet, but we've given a good deal of time to discussion of them. We feel that the portion dealing with maintaining the screen and balance, that is side-to-side and corner-to-corner, both on the same screen and between projectors, is something for which we can arrive at a workable recommendation fairly quickly. The other, as to just what the distribution should be, whether it should be 80%, 100%, 65% side-to-center, is going to be a more difficult job.

Mr. Geib: Harry Rubin of Paramount Pictures has just suggested that this work be continued because it is going to lead to better projection.

Dr. Lozier: We certainly hope so. We're meeting very good cooperation from various people who are looking forward to appearance of this information in the *Journal*. The material will then be available to the public to use in any way it sees fit.

The Committee W. W. Lozier, *Chairman*

Herbert Barnett	W. F. Little
H. J. Benham	L. J. Patton
F. E. Carlson	Leonard Satz
M. H. Chamberlin	J. W. Servies
E. R. Geib	B. A. Silard
L. T. Goldsmith	Allen Stimson
L. D. Grignon	C. R. Underhill, Jr.
A. J. Hatch, Jr.	H. E. White
L. B. Isaac	A. T. Williams
W. F. Kelley	D. L. Williams
F. J. Kolb	

70th Semiannual Convention

Close technical ties between movies and TV were a "natural" phenomenon clearly apparent throughout the Society's 70th Semiannual Convention in Hollywood last month. From the luncheon at the Hollywood Roosevelt Hotel on Monday, October 15, to the closing session on Friday evening, 600 engineers who took part repeated over and over the *movies-TV* theme. Not only did registration hit a high mark for West Coast conventions, but also attendance at the luncheon and at the Wednesday banquet far exceeded expectations. Even the heavier-than-usual program of 65 technical papers closely packed into 12 sessions failed to exhaust the energies of technical people who came to hear or be heard.

On the next few pages are luncheon remarks made by our President and skillful master of ceremonies, Peter Mole, and by the guest speakers: Donn Tatum, Director of Television, American Broadcasting Company, Hollywood, and Jerry Wald of Wald-Krasna Productions, Hollywood. All three hit the front pages of all motion picture and television trade papers and a fair share of East and West Coast newspapers the following day.

Get-Together Luncheon Remarks by President Mole

[We convened] our 70th Semiannual Convention with a much rosier picture than prevailed at the time of the New York meeting last spring. Since then a concentrated program of selling entertainment to the public has been under way. The motion picture industry has rediscovered the few million people who are willing to spend money to see good motion picture entertainment, and the actor, writer and director ambassadors of good will are speeding to the four corners of the country to stimulate attendance in the motion picture theaters.

All this is as it should be—a deliberate and successful effort to attract the famous entertainment dollar.

Coast-to-coast television was initiated with the signing of the Japanese Peace Treaty in San Francisco. Theater television is developing by leaps and bounds, stimulated by special showings such as the Robinson-Turpin fight in New York. I believe that movies and television are now finding a common ground for their mutual benefit and will complement each other.

These developments should encourage the members of this organization and their associated companies to continue their scientific research in the belief that the entertainment business will continue to expand and that production will need better tools with which to work.

I remarked at the Spring Convention on the lack of unified effort between the engineer, producer and exhibitor. I see no reason yet to change my views. Nor do I see reason to alter my belief that a successful future for the producer and exhibitor depends upon a close alliance with the engineer.

In the past, the production end of our industry has been the recipient of many technical advances brought about by forward thinking men who had the courage to spend time and money on the development of new ideas. From these engineers who carried on their work outside the field of motion pictures came sound and color. Now, in this time of optimism the producers and exhibitors must take the initiative. They must push vigorously for new technical developments and they must be sympathetic to research work in their planning.

Although sound and color came to the motion picture industry from outside interests, further new developments may not materialize in a finished form unless the industry shows a willingness to share in the program. Equipment manufacturers can no longer be expected to do research and development work on speculation. The exhibitors who plan to use theater television or wide-angle projection must share at least part of the engineering burden. Producers who wish to adopt new sound recording methods or improved color processes, must share in the development as well.

It is our way of business life to risk capital—to produce more business and to secure greater benefits—and we should continue this practice. The time is here to complete the cycle on current developments. The capital has been ventured. It still remains to be recovered through acceptance by the industry of technical developments already being offered by the engineers.

As for the future: We must go forward—focus our attention on other engineering advances not yet introduced. And we must concentrate on things that hold promise of enhancing the entertainment values that are the life blood of our industry.

Excerpts From Address by Don Tatum

"Television broadcasting and motion pictures are not mutually exclusive media of communication and entertainment. They will complement each other, each occupying its own particular and important niche in the lives of the American people. A very substantial part of all the television programming will be produced on motion picture film and the great pool of administrative, creative, artistic and technological talent, as well as the magnificent production facilities of the motion picture industry, will constantly and steadily be more and more devoted to the making of filmed television programs.

"When the current allocation problems have been resolved and television becomes a full-blown national medium as more and more television stations come on the air, the impact of this new medium will work changes in the business and the methods of producing motion pictures for theater exhibition purposes. There will be fewer theaters, film costs will go down and there will be fewer motion pictures made for theater exhibition than has been the norm up to the present time. This means that there will be major motion picture studio capacity available for the making of television films and at lower costs than is presently possible.

"There are many similarities in the methods, techniques and objectives of television broadcast programs and motion picture films, but they are not identical. From the creative standpoint, there are close analogies in the techniques of writing and directing and acting, but writing or directing or acting in a television program is a different thing from performing the same functions in the making of a motion picture. The same is true of the technical end. Lighting a motion picture for theater projection and lighting one primarily for television purposes is different; and the requirements with respect to scenery and sets and the like are different.

"The objectives and the end results are different. Under our free system of broadcasting, the television industry must be supported by advertising revenues. As a result, more and more we shall note that television programming, whether live or on film, will come to reflect the necessity for constructing and tempering the programs so as to best serve the needs and the requirements of advertisers while continuing to serve the public interest and to satisfy the requirements of the television viewing public.

"For the same reasons, the importance in television broadcasting of feature length motion pictures made primarily for theater purposes will constantly diminish. This tendency will inevitably result from the different requirements in the two media with respect to time of the program, costs, production techniques and the difficulty of accomplishing with a feature length motion picture that close relationship between the program content and the advertising objective of a television program no matter what may be its form. For that reason I believe that some of the estimates that have been bandied about of the enormous potential value of motion picture libraries now in the vaults of the major motion picture producing companies will prove to be highly excessive.

"I would like to add my confirmation to the point of view which I know is shared by many of the leaders of the SMPTE: that what we should have is a large scale independent research program in which both our businesses would share and in which we would pool our resources and know-how.

"To those in the television business and to those in the motion picture business who look upon each other with distrust, suspicion and sometimes scorn, I would say forget your differences and accept each other because that is what you are inevitably going to have to do. To those in the motion picture business who say that television is simply an extension of the art of making motion pictures, let me say that you are wrong and that there will be no complete marriage of the two."

Excerpts From Speech by Jerry Wald

"Thirty-five years ago, you engineers joined up with a business which, primitive as it was, entertained an easily satisfied public, and made good money.

"It would have been easy then to say, 'The public likes these cowboy and Indian thrillers, and custard pie tossing orgies, even though they shake like a shimmy dancer. As long as the customers cheer when the cavalry rides to the rescue, and howl when the comic takes a pratt fall, or receives a pie in the face . . . why bother about the shakes and shimmies, the flickers and the frequent blackouts? Let's don't throw a monkey wrench into a machine that turns out dimes and nickels, faulty as it is.'

"Luckily, the inventive mind doesn't work that way. You engineers went to work on the machine, and you've been working on it ever since. As a result, you've got us one that turns out dollars instead of nickels and dimes.

"The creative end of our business . . . I don't like that term because if any people in this business are creators the engineers are . . . but I'll use it for want of a better one . . . has of course advanced with you. Sometimes I feel we've been pulled along. Again, the advances have been made by sheer inspiration, and, again, by careful plodding and intelligent planning."

Mr. Wald went on to discuss the much-discussed health of the motion picture industry and expressed a robust optimism with the reminder that he and his partner Norman Krasna have recently launched a $50,000,000 production schedule at RKO, consisting of 60 motion pictures to be filmed over a five-year period.

"With your continued magnificent technical assistance," he concluded, "we will achieve a future that will, by comparison, make the golden past seem like the dark ages."

Following Jerry Wald's spirited address at the Monday luncheon, our Society's David Sarnoff Gold Medal was presented to the initial recipient, Otto H. Schade, for technical contributions to television. A full story about this portion of the Monday program will appear in the December *Journal* along with a detailed account of several other awards including the Warner and Progress Medals which were presented during the Wednesday evening banquet. A complete and accurate list of all papers presented during the 70th Convention arranged in order of actual presentation and including the names of all authors with company affiliations will be the last item in the December *Journal*.

Technical sessions Monday afternoon and evening at the Hotel and Tuesday evening at CBS' Studio A concentrated heavily on television. High-speed photography papers filled the Tuesday morning and afternoon sessions while on Wednesday a group of "high speeders" were guests of the Naval Ordnance Test Station at Inyokern, Calif. On Friday morning another group participated in a desert photographic experiment where atmospheric conditions were favorable and they could concentrate on certain philosophical rather than technical aspects of rapid motion photography.

The Wednesday morning session at the Hotel was devoted to 16-mm film and its use in television and training. After a $1\frac{1}{2}$-hour warm-up on formal papers there was a most enthusiastic panel discussion of the 16-mm emulsion position question. Difficulties have occurred in

the use of 16-mm prints for television broadcasting because certain methods of film production yield 16-mm release prints with emulsion facing the projection lamp, the nonstandard position. When nonstandard release prints are spliced together with prints having standard emulsion position the broadcasters have picture and sound focusing troubles that are rarely predictable. This problem and what can be done about it were considered verbally and at length. The entire discussion was recorded and has been mimeographed for distribution to all participants for review. It will be printed in full in an early issue of the *Journal.* Echoes from the emulsion-position debate were still reverberating when the laboratory session was called to order Wednesday afternoon.

As in most of the Society's recent Conventions, magnetic recording occupied a fair share of the program. Thursday morning and afternoon were entirely devoted to papers on this subject, supplemented by an unscheduled but well attended forum on proposed standards for 35-mm magnetic-track placement that followed the last morning paper. The discussion ran until after 1:30 p.m., forcing a thirty-minute delay in the start of the afternoon papers. Conflicting recommendations were based upon conflicting performance data. Because eventual American standards for track location will be with us for a long time to come they must have a broad and acceptable basis in experience; therefore the entire discussion will be published in the earliest possible issue of *Journal.*

Several different types of three-color motion picture release print films were described and demonstrated during the session on Thursday evening at the Republic Studios scoring stage. Papers on various aspects of lighting were grouped into the Friday afternoon session at the Hotel. That evening the past caught up with the future at the Paramount Studio Theater where several methods of producing pseudoscopic and stereoscopic motion pictures were described and demonstrated with varying degrees of clarity.

As the final session ground to an official halt, there was unanimous agreement that the papers and the local arrangements committees had *really* put on a show. Everyone was exhausted including the usually indefatigable Bill Kunzmann who was glad to see his 70th Convention in 35 years become one with history

Special credit for a good job well done should go to:

Fred Albin, American Broadcasting Company, Hollywood, Papers Committee Vice-Chairman, and in charge of the Papers program for the 70th Convention;

Charles R. Daily, Paramount Pictures, Hollywood, Chairman of Local Arrangements, who organized the sessions held away from the Hotel including particularly the special facilities for the session on stereo motion pictures;

Ed Templin, Westrex, Hollywood, in charge of public address equipment and discussion recording;

Norwood Simmons, Eastman Kodak, Hollywood, "Secretary-General" who planned and supervised both luncheon and banquet programs;

Harold Desfor, RCA, Camden, and *Walter Simons*, Altec Lansing, Hollywood, proficient purveyors of publicity; and

Clyde Cooley and *Frank Erler* who operated film and slide projectors at times under very difficult conditions.

Ladies from all corners of the United States who attended took full advantage of the well organized program prepared for them by the Ladies Committee under the superior administration of Mrs. Charles R. Daily. There were radio and television shows, a luncheon with a costume show and tour of Universal Studios, a tea at the Beverly Hills Hotel and, of course, the Convention luncheon and banquet. Headquarters for the Ladies Committee remained open all week and became the regular gathering place for the fairer participants.

On Tuesday evening officers and staff members of the Society were dinner guests of the Motion Picture Research Council at Chasen's Restaurant. The men who guide the destinies of both engineering organizations enjoyed not only the drinks and fine meal served with customary movie capital hospitality but also welcomed the opportunity to talk shop informally for a couple of hours with men from different ends of the business, including television.

Engineering Committee Meetings

Six Engineering Committees met during the 70th Convention; three at the Headquarters of the American Society of Cinematographers (High-Speed Photography, Sound, Film Dimensions) and three at the Staff Engineer's suite in the Hollywood Roosevelt Hotel.

High-Speed Photography. This Committee, Chaired by John Waddell, met Monday afternoon with an attendance of four Committee members and 14 guests. The key activities consisted of an outline of future Committee work and an effort to expand the work of the Society to better serve the West Coast high-speed photography members.

Sound. This Committee, Chaired by Lloyd Goldsmith, met Tuesday morning with an attendance of 11 members and 15 guests. A very considerable agenda was thoroughly discussed and concrete action undertaken for the future. Key issues were the questions of edge guiding and magnetic recording standards and test films.

Laboratory Practice. Chaired by John Stott, this Committee met Tuesday afternoon with 10 members and guests attending. Several items of importance were discussed and definitive progress made on proposals for negative cuing for printer light changing and brightness of screens in laboratory review rooms.

Color. This Committee, Chaired by Herman Duerr, met Wednesday morning with a rather small attendance of six members and guests. The small attendance precluded any specific actions, but did permit a general but useful discussion on several of the projects before the Committee.

Screen Brightness. Chaired by Wallace Lozier, the Thursday afternoon meeting of this Committee was attended by 10 members and guests who discussed methods of utilizing the theater survey recently completed. In addition, a first draft of the revision of the screen brightness Standard was agreed upon.

Film Dimensions. This Committee, Chaired by A. C. Robertson (alternate for E. K. Carver), met Friday afternoon with a total attendance of six members and guests. Despite the attendance, there was an excellent discussion on low-shrink film and a first draft of a Standard was agreed upon for circulation to the full Committee.

Board of Governors Meeting

The fourth meeting of the Board of Governors during 1951 was held on Saturday morning, October 13, at the Hollywood Roosevelt Hotel in Hollywood, California. It preceded by two days the opening of the Society's 70th Semiannual Convention also held at the Hollywood Roosevelt, and was remarkably well attended. The meeting ended early in the afternoon. A number of Board members left immediately for a chuck wagon dinner sponsored by the Theater Equipment and Supply Manufacturers Association.

FINANCIAL

R. B. Austrian presented the third quarterly financial statement and in the absence of F. E. Cahill, Jr., Treasurer, also read the treasurer's report. It was noted that test film sales, financial aspects of publications and all other administrative operations were within the limits of the 1951 budget. Loss of members who were delinquent in payment of dues continues to be a serious problem. On September 30 there were 300 delinquent members, each of whom had received two membership dues bills and two written invitations for reinstatement. Although still high, this figure had been reduced from 395, the total of delinquent members on June 30, 1951.

The Board was also advised that while recuperating from a recent operation Pierre Mertz saw in a New York newspaper a list of unclaimed monies in the Chase National Bank. He discovered that the list included a "Society of Motion Picture Engineers, address unknown." Dr. Mertz notified headquarters and Mr. Muskat contacted the bank, arranging to pick up an amount of $101.00 that was found to be an unclaimed foreign bank draft held open by the bank since 1936.

As Chairman of the Sustaining Memberships Committee Mr. Sponable, Past-President, reported that he had recently approved the printing of an illustrated brochure to be sent promptly to all Sustaining members of the Society with an individual letter inviting a nominal increase in Sustaining support. He pointed out that this would be the beginning of the Society's Sustaining campaign for 1952 and would ultimately include invitations to a large number of businesses not now represented. He received the suggestion that the large number of television film producers whose work is guided technically by the Society be invited to support the Society's technical work through the medium of Sustaining memberships.

ENGINEERING

F. T. Bowditch, Engineering Vice-President, invited the Board's attention to the schedule of six engineering committee meetings planned for Convention week. A brief report on these committee meetings appears elsewhere in this issue of the *Journal*. Nearly all of the engineering committees had been busy for the past several months reviewing current American standards preparatory to listing for the International Organization for Standardization the ones most suitable for consideration as future international standards. In this connection he pointed out that there had been little real interest among ASA's Photo Correlating Committee in the field of international motion picture standards and that, consequently, there was little enthusiasm for a projected meeting on this subject in New York during June 1952. Since these were the views generally held by engineers in the eastern part of the United States, Mr. Bowditch reported his plan to sound out a number of West Coast opinions on the merits of international standards for motion pictures and on the projected meeting.

If held, host for the international meeting would be Sectional Committee PH22. It had been this committee's view that the meeting should be called if a satisfactory agenda could be developed by early 1952. In that case ASA would be asked to send out the official call for the meeting early in January so that delegates could make their plans in ample time to attend.

There was also extended discussion of a glossary project that had received some attention over the past ten years but had never been attacked vigorously. Mr. Carlson, a Governor and also Chairman of the Standards Committee of the Society, reported that he had arranged for the engineering committees to revive this job by working on a number of sections which Hank Kogel, Staff Engineer, was, at that moment, organizing.

As a matter of interest it was noted that the proposed FCC theater television hearings were again postponed—from November 26, 1951, to February 25, 1952.

Boyce Nemec, Executive Secretary, reported on a meeting of study group 10 of the International Radio Consultative Committee (CCIR) which he and G. L. Dimmick, Magnetic Recording Subcommittee Chairman, had attended in Washington on September 27. Sound recording characteristics was the subject of the session and the meeting was under the chairmanship of Neal McNaughton of the National Association of Radio and Television Broadcasters. He was appointed Chairman of the study group at the VI Plenary Assembly of the CCIR, which was held in Geneva from June 5 to July 6, 1951.

Purpose of the meeting was the discussion of recording characteristics for disk and magnetic records used in the international exchange of radio program material. The technical aspects of the problem were not considered by the Board, but Mr. Nemec expressed some concern over the sudden interest shown by CCIR, a telecommunications regulatory body in the field of industrial international standards. There was an apparent conflict with similar activities now beginning to move through the ASA–ISO channels and Mr. Bowditch offered to look into the question more thoroughly with the object of forming an official SMPTE policy.

EDITORIAL

J. G. Frayne, Editorial Vice-President, reported that his share of program arrangements for the 70th Convention was already completed and that the success of the Papers Committee had been largely the result of efforts by Fred Albin, West Coast Vice-Chairman, and E. S. Seeley, Chairman of the Papers Committee. Ed Templin, Chairman of the West Coast Public Address and Recording Committee,

had set up and operated the public address equipment built by Fred Whitney, headquarters engineer. Mr. Templin had also arranged to check out all of the sound engineers who were scheduled to operate the equipment during the Convention. Standardized operating techniques were developed and that job was running smoothly for the first time in many years. Messrs. Frayne and Grignon reported upon the work of Grignon's Society Emblem Committee and the Board selected one of three committee recommendations as the final emblem to be worked into the *Journal* cover, stationery, and perhaps lapel pins. The design had been developed by Melvin Stewart, a West Coast design student, and Mr. Grignon was authorized to convey the Board's gratitude for his serious contribution.

NEW SUBSECTION

C. R. Daily, Chairman of the Pacific Coast Section, discussed a request from a number of Society members in the San Francisco area for permission to form a local subsection under the administrative guidance of the existing Pacific Coast Section Board of Managers. P. A. Williams, who served as spokesman for the San Francisco group, had cited the subsection provisions of the IRE constitution and submitted persuasive argument in favor of a parallel organization within this Society. The Board resolved to authorize such a subsection under the proposed arrangement, and Dr. Daily was instructed to advise Mr. Williams and his associates that the Society would support a program of meetings under the Pacific Coast Section Board of Managers.

CONVENTIONS

W. C. Kunzmann, Convention Vice-President, reported that all arrangement for the 70th Convention had been crystallized and that he had made firm commitments for four additional conventions:

71st: Hotel Drake, Chicago, Ill., April 21–25, 1952.

72nd: Hotel Statler, Washington, D.C., October 5–10, 1952.

73rd: Hotel Statler, Los Angeles, Calif., April 26–30, 1953.

74th: Hotel Statler, New York, N.Y., October 1953.

For several years the Board of Governors had considered the merits of replacing the Spring Convention with a series of regional meetings, each of perhaps a day's duration, to be held in areas away from the usual Convention cities and at times when it was unlikely that local people would be attending distant national meetings. The notably successful regional meetings arranged in recent years by the Central Section in Cleveland, Toledo and Detroit were evidence that members in those cities, who are rarely able to attend national conventions, will support occasional meetings "at home." There was extended consideration of *Journal* and Papers complications that might result from such a major change in the Society's convention practices. It had also been suggested that even if the Society were to continue holding two national Conventions each year a series of regional meetings would be of substantial benefit to the Society from a membership standpoint and would also give members in areas where there is considerable motion picture or television activity an opportunity to discuss their mutual problems under professional-technical auspices. No conclusions were reached but the Board will continue to keep a watchful eye on such affairs as the Central Section regional meetings scheduled for Dallas, Texas, on November 7, and for Chicago on November 10.

ELECTIONS

Before concluding the meeting President Mole announced the results of the Society election for 1951. The following officers assume office on January 1, 1952, for a two-year term ending December 31, 1953.

Frank E. Cahill, Jr., Financial Vice-President

Barton Kreuzer, Treasurer

Fred T. Bowditch, Engineering Vice-President

J. E. Aiken, Governor, Atlantic Coast

Axel G. Jensen, Governor, Atlantic Coast

G. W. Colburn, Governor, Central Section

E. W. D'Arcy, Governor, Central Section

F. G. Albin, Governor, Pacific Coast

J. K. Hilliard, Governor, Pacific Coast

Although all section election returns were not completed in time for the Board meeting, the new Boards of Managers were announced subsequently as follows:

Atlantic Coast Section

E. M. Stifle, Chairman, reelected
H. C. Milholland, Secretary-Treasurer, reelected
Frank N. Gillette, Manager 1952–1953
John G. Stott, Manager, 1952–1953
Richard Hodgson, Manager, 1952–1953

Central Section

C. E. Heppberger, Chairman, 1952
James L. Wassell, Secretary, 1952
Kenneth M. Mason, Manager, 1952–1953
James E. Dickert, Manager, 1952–1953
William C. Eddy, Manager, 1952–1953
Reid H. Ray, Manager (appointed to fill out Howard T. Nuttall's term), 1952

Pacific Coast Section

Vaughn C. Shaner, Chairman, 1952
Phillip C. Caldwell, Secretary-Treasurer, 1952
Arthur C. Blaney, Manager, 1952–1953
Linwood G. Dunn, Manager, 1952–1953
Alan M. Gundelfinger, Manager, 1952–1953

Engineering Activities

Six Engineering Committees utilized the recent 70th Convention as a desirable time and place to meet. The highlights of the first three meetings are outlined below; the other three will be described in the next *Journal*.

High-Speed Photography

1. Scope and Name of Committee. Photography has been playing an increasing role in the solution of diverse engineering problems. This fact led the Committee to apply to the Board of Governors for a change in scope (and name) to encompass all such applications. The Chairman advised the group that the request had been rejected to preclude consideration of non-motion picture aspects of photography. It was understood, however, that all engineering uses of motion picture photography, whether high-speed or not, properly fall within the scope of the present committee.

2. West Coast Members. Their problems were discussed at length. These stem from their desire to have the Committee serve a dual function, part Engineering Committee and part Society Section. The suggestion was made that this latter role be correlated with other West Coast Section activity. Arrangements for this have since been made and Roy Wolford has been delegated to work through Charles Daily, Vaughn Shaner and the Section Program Chairman who still is to be appointed.

3. Future Committee Work. It was noted in general terms that a need exists for standards in high-speed photography equipment and that this would be given a high priority at subsequent meetings.

4. Next Symposium. At the Chairman's request Mr. Painter accepted the responsibility for organizing the next symposium at the coming Chicago Convention.

5. New Chairman. Mr. Waddell is to step down at the end of the year, in accordance with requirements of the Bylaws, and at that time a new chairman will be appointed.

Sound

1. Edge Guiding. The recent ballot on revision of PH22.41, PH22.80 and PH22.81 was far from decisive and merely served to emphasize the division existing on the subject. It was felt that the ballot should have contained a more extensive story on the pros and cons of the issue. In addition a fourth alternative was proposed: guide the perforated edge at the picture gate and the sound track edge at the sound head. A Subcommittee was formed, chaired by Malcolm Townsley, to prepare a report of all the factors for use as background material in a new ballot on the question.

2. International Standardization. The group endorsed the program of international standards activity as proposed by Lloyd Goldsmith, Chairman, and Fred Bowditch, Engineering Vice-President.

3. *Nomenclature for Electric Filters, PH22.33-1941.* This was never an American Standard but rather a Recommendation (an ASA classification which no longer exists). The committee was asked to recommend that it be either standardized or dropped. The consensus was that it

was useful at the time of origin but no longer used or needed, and the latter recommendation was voted. The next step is action by the Standards Committee.

4. Magnetic Recording Subcommittee Report. In the absence of Glenn Dimmick, John Frayne made the report. This led to a very broad and thorough discussion on various aspects of magnetic recording and in turn to recommendations to the Subcommittee that it give consideration to a standard for full-width coated 16-mm double-perforated film, additional test films, and striped magnetic film. The Subcommittee was thanked for its excellent work to date.

5. New Test Film Proposed. The need for a scanning illumination intermodulation test film in testing 16-mm projectors was mentioned and concrete proposals for achieving this were agreed on.

6. End of Term. Lloyd Goldsmith is leaving the Chairmanship at the end of the year in accordance with the Bylaw requirements. He thanked the Committee for its fine support these past four years.

Laboratory Practice

1. Negative Cuing Proposal. The Committee has been working on this problem for quite some time and has finally come to the conclusion that the light change cuing device would have to be something other than a notch in the negative if a standard were to be produced. Lloyd Thompson of the Calvin Company has been working on an electrical cuing technique and announced at the meeting that this has been perfected, and is available, patent clear, to the Committee for standardization. This offer was accepted with thanks and plans were made to circularize all committee members and laboratories for comments.

2. 16-Mm Review Room Screen Brightness. After a thorough discussion of the problem and a review of recent survey results it was decided to attempt standardization of the screen brightness of laboratory 16-mm review rooms. A Subcommittee formed previously was asked to draft a proposed standard specifying 14 ft. candles ± some tolerance, use of a white matte screen and the type of meter to be used in making the measurement. This will also be circulated to all committee members and laboratories.

3. Chemical Engineering Abstracts. John Stott, Chairman, called attention to the "Chemical Corner" recently established in the *Journal*, consisting of items and abstracts of interest to laboratories. He praised Irving Ewig for the one-man job he has been doing on this and noted the difficulty of one man continuing the job all alone. He asked all committee members (and any others who may be interested) to send Ewig items of interest from their varied reading, to keep this corner alive.—*Henry Kogel.*

Inter-Society Color Council Meeting

The Inter-Society Color Council is preparing its program for the 1952 Spring meeting to be held February 7–9 at the Statler Hotel in New York. The theme of the meeting is to be "Color in Science, Art, and Industry." The subject matter for the two days is divided between the techniques in the study of color itself, and the various uses color is put to in our time. Some of the topics to be discussed the first morning are, "The Color of Oils," Procter Thomson; "Functional Color," Faber Birren; "Color Reproduction," Arthur C. Hardy; and "Color in Television," Peter C. Goldmark. In the afternoon, Deane B. Judd will report on the ICI meeting at Stockholm; W. D. Wright and Ralph M. Evans, respectively, will discuss "Color in Relation to Vision and to Photography."

The following day such subjects will be discussed as the "Appearances of Color," Harry Helson; "Merchandising of Color," Kenneth C. Welch; "Color in Abstract Movies," A. H. King; "Color for Interiors," Gladys Miller; "Textiles," E. I. Stearns; and "Artists Colors," Martin Fischer. In the evening, I. A. Balinkin will present a special demonstration of "Color Phenomena." At the morning session on February 9 reports of technical committee activities will be received and discussed, and delegates of each of the 21 member associations will summarize their 1951 activities in color.

An exhibit, to be held as a part of this annual meeting, promises considerable interest. Over half of the ISCC's Member Bodies already have agreed to take part, and certain of the technical committees will prepare exhibits relating to their work. By means of these exhibits members may become acquainted with the many prob-

lems and activities of ISCC member associations.

The Nominating Committee of the ISCC has announced the following slate for 1952–53 officers: *Chairman*, E. I. Stearns (AATCC and IMG); *Vice-Chairman*, C. R. Conquergood (NAPIM and IMG); *Secretary*, Dorothy Nickerson (OSA and IMG); *Treasurer*, Norman Macbeth (IES); and *Counsellors*, I. A. Balinkin (outgoing Chairman (ACerS)), Waldron Faulkner (AIA), Gladys Miller (AID), Procter Thomson (AOCS), and Frank J. O'Neil (AATCC and IMG).—*Dorothy Nickerson*, Cotton Branch, PMA, U.S. Dept. Agriculture, Washington 25, D.C.

Book Reviews

Ideas on Film (A Handbook for the 16-Mm Film User)

Edited by Cecile Starr. Published (1951) by Funk & Wagnalls Co., 153 E. 24 St., New York 10. i-xix + 238 pp. + 11 pp. index. 6 × 9 in. Price $4.50.

The main purpose of this volume is to acquaint nontheatrical film users with the problems of production and sponsorship of documentary and educational pictures, and to suggest criteria of choice to the ever-increasing legions of these consumers. Miss Starr, as Nontheatrical Film Editor of the *Saturday Review of Literature*, has used wisely the columns of her magazine to serve precisely that end, and the articles of a score of her distinguished contributors form the body of this intelligent and articulate book.

The multifaceted aspect of the non-theatrical field is examined by such experts as Rudolph Arnheim, Julien Bryan, Kenneth Macgowan, Arthur Meyer, Raymond Spottiswoode, Willard Van Dyke and many others; each in his own sphere scrutinizes the challenge of the "idea" film and discusses its prospect as an expanding factor in our country's intellectual maturing. Miss Starr herself contributes important articles on a variety of subjects, in addition to selecting a list of reviews of some 200 top documentary and educational pictures, and compiling other essential data for the users of 16-mm film.

The foreword, by Irving Jacoby, tackles the basic problem of these films' purpose, which is "essentially to influence what people think." "In these troubled days," writes Mr. Jacoby, "when our freedoms and our dignities are under attack from all sides, we may not at first like the idea of being 'influenced' or even of 'influencing,' for the word carries overtones of violence, expediency, and even contempt for the object that is to be won, changed, and redirected: the human mind." This clear understanding of the nontheatrical film's "propaganda" mission establishes, with eloquence and persuasion, the proper perspective for the whole book.

Miss Starr's collaborators are well aware of this essential nature of their chosen field, and their substantial measure of success in its theoretical and practical manifestations is what makes *Ideas on Film* a valuable and penetrating contribution to our grasp of the complexities of our times.—*George L. George*, Screen Directors Guild, New York.

Fundamentals of Vacuum Tubes

By Austin V. Eastman. Published (1949) by McGraw-Hill, 330 W. 42nd St., New York 18, N.Y. i-xxi + 600 pp. + 30 pp. appendix + 13 pp. index. 460 illus. 6 × 9 in. Price $6.00.

Updating a long-valuable reference and study text, this third edition has revisions occasioned principally by natural advances in electron tubes. In the main, the changes are those which new types have made necessary, and many obsolete tube types have been deleted. Specific improvements over the second edition include a more complete description of the phenomena of current flow through gases, an enlargement to more useful size of many of the charts depicting tube characteristics, and a revised treatment of audio amplifiers to include the concept of gain treated as a vector, taking into consideration the phase angle of the amplifier and its effect on absolute gain and frequency response.

In view of the widespread use of voltage-multiplying circuits in many current

electronic applications, the information on this subject has been enlarged appreciably. A general rearrangement of much of the material provides separate chapters on modulators and demodulators, with much new material on pulse-width, pulse-time, and pulse-amplitude circuits, with a satisfactory analysis of these relatively unfamiliar applications. The material on power series analysis has been expanded into a separate chapter with improved clarity and usefulness.

As in previous editions, the referencing to earlier literature is complete and thorough, making the book one of value to the student as well as to the more advanced reader who may use the volume as a refresher.—*C. G. McProud*, Editor, Audio Engineering, 342 Madison Ave., New York 17, N.Y.

Kino Geraete Technik

By Dr.-Ing. Harald Weise. *In German.* Published (1950) by Akademische Verlagsgesellschaft, Geest & Portig K.-G., Leipzig C 1, Germany. 364 pp. Many schematic and line drawings. 16 pp. supplement of equipment photographs. 6 × $8^1/_4$ in. Available in U.S. from Stechert-Hafner, Inc., 31 East 10th St., N.Y. 3. Price $5.00.

It is rare that one encounters a comparative work on mechanism design which manages to present a thorough study of the fundamental kinematics, as well as complete functional descriptions of the equipment. In the German-language volume, *Kino Geraete Technik*, the designer of motion picture apparatus is fortunate in finding just such a work.

This is the first part of a proposed two-volume set on substandard (8-mm and 16-mm) motion picture equipment, of which the volume here reviewed deals with cameras. Volume 2 will deal with projection apparatus. The author says in his foreword that additional similar works on theatrical (35-mm) and still equipment are in preparation.

Anyone familiar with the problems of optical and mechanical mechanism design is likely to be awed by the painstaking detail with which each component of the many makes of equipment has been analyzed. The author has reduced to their fundamental principles film drives, intermittent movements, film paths, registration devices, mirror and prism systems, shutters, motors, governors, counters, magazines, etc. The task seems all the more impressive when one notes the author's statement that his data were derived primarily from sample units, photographs, catalogs, and technical papers, and only in rare instances from manufacturers' drawings. Thus the book is truly a monumental achievement in careful measurement and analysis.

It is this exceptional accuracy, and the care taken to preserve correct proportions and "unitless" diagrams, which make *Kino Geraete Technik* so valuable to the motion picture equipment designer. In addition, manufacturers and personnel utilizing motion picture apparatus in research work and photographic instrumentation will be able to gain much qualitative and quantitative information from this book.

From its early chapters on the basic physical and physiological factors of the motion picture medium, right through its exhaustive bibliography and pictorial supplement, the work is clearly and concisely written, and liberally illustrated with diagrams and graphs. An effort has been made to trace the historical evolution of many of the mechanisms, giving an insight into the trial-and-error progress of the art, and pointing the way toward future development.—*Peter V. Norden*, J. A. Maurer, Inc., 37–01 31st St., Long Island City 1, N.Y.

Journal indexes covering the thirty-four years from 1916 through 1950 may be purchased from Society Headquarters.

1916–1930	$1.25	1930–1935	$1.25	1936–1945	$2.00	1946–1950	$1.50

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal*.

Style and the Journal

Style is a small but important aspect of editing this *Journal.* The staff is preparing a Style Manual for which suggestions are welcomed from contributors to, as well as readers of, the *Journal.*

The Style Manual will contain the usual specifications and advice for the physical arrangement, organization and presentation of Society papers, which are aspects currently being very well accomplished by most authors for the *Journal.*

This *Journal*, like all periodicals, is copy-edited in accordance with chosen rules of spelling, punctuation and abbreviation. These rules and lists of examples will make up a large portion of the Style Manual. The Editor would like to hear from any readers who have pet peeves or favorites in matters of style.

The *Journal's* style is being continually evolved on the basis of experience with the *Journal's* own subject matter. The style does, however, generally follow these standard reference works: the *Merriam-Webster Dictionary*, the American Standards Association's "Abbreviations for Scientific and Engineering Terms, ASA Z10.1–1941," the American Institute of Physics' "Style Manual," the American Chemical Society's "List of Periodicals," "Subject Index," and its "Directions for Assistant Editors and Abstractors of Chemical Abstracts."

The *Merriam-Webster Dictionary* covers a surprisingly large number of points of style in motion picture and other technical terminology, a few examples of which are: by-pass, cutoff (as noun), disk, infrared, nonlinear, selsyn and theater. We cannot, however, always follow the dictionary because the dictionary is a reference of recorded usage and we must often lead in establishing usage. The Style Manual will list deviations such as the following: blackbody, overall, peephole, viewfinder and wavelength.

Abbreviations are used whenever it is believed they make reading easier and faster for the average reader. The abbreviations are almost always those in ASA Z10.1–1941, although that document is not always the last word since it is now ten years old. For instance, ASA gives megacycle spelled out; we use mc. Not so readily resolved is the abbreviating of cycles per second. ASA shows "spell out or use c"; the American Institute of Physics says abbreviate as cps. Using c or cps would appear logical, but in the *Journal* we often have the term frames per second, which cannot become fps because that stands for feet per second; therefore the *Journal* now uses cycle/sec and frame/sec, although in simple references it is acceptable to say 60-cycle power rather than 60-cycle/sec power.

The *Journal* now uses the abbreviations 16-mm and 35-mm in text and 16-Mm and 35-Mm in display lines. There are many variations current and it seems time to adopt one which is especially suited to our field — 16mm and 35mm. This seems less appropriate for 8mm, 17½mm and 32mm, but for the sake of consistency they should also be used. It is felt that 16mm and 35mm are customary enough so that the extended usage will read easily and not obtrude on the reader.

The brief exposition above has been put as impersonally as possible because the parts of style dealt with are those few matters which must be consistent throughout the publication and cannot be left to the personal choice of *Journal* writers; however, particularly at this time, any expression of personal preferences and the reasons therefor, on any points of copy-editing style, will be welcomed. Also, please advise the Editor whether you would be willing to review parts of the Style Manual if it were mimeographed for circulation and comment.

While we are crystallizing these details, the editorial policy will continue to be that of adhering to as much of each author's individual style as will not seriously detract from the efficient reading and enjoyment of his paper. Indeed, there is now in process a paper which will probably be published with the pronoun "I" sprinkled throughout. We are not going to rewrite or revamp papers so that they all read alike in the *Journal.*

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY.

Honorary (**H**) Fellow (**F**) Active (**M**) Associate (**A**) Student (**S**)

Ahern, William R., Lighting Director, National Broadcasting Co. **Mail:** 63 Laurel St., Floral Park, Long Island, N.Y. (**M**)

Atchley, Dana W., Jr., Engineer, United Paramount Theatres, Inc. **Mail:** 6 Chandler St., Lexington, Mass. (**M**)

Baker, C. T., Jr., Presbyterian Minister, Visual Aids Producer. **Mail:** 1122 Greenfield Ave., Nashville, Tenn. (**A**)

Barragan, R. W., Engineer. **Mail:** 1043 Park, El Centro, Calif. (**A**)

Betts, Howard B., Vice-President, Optomechanisms, Inc. **Mail:** 1079 E. 28 St., Brooklyn 10, N.Y. (**M**)

Boggs, Chester A., Engineer, Century Engineering, Inc. **Mail:** 1938 Mill Rd., South Pasadena, Calif. (**M**)

Boots, Paul K., School of Radio Technique. **Mail:** West Side YMCA, 5 West 63 St., New York 23, N.Y. (**S**)

Boylan, Edward M., Sensitometrist, U.S. Army (Reserve—Active Duty). **Mail:** 44 Holden St., Rochester, N.Y. (**M**)

Coleman, R. E., Manager, Kearse Theatre. **Mail:** PO Box 1133, Charleston 23, W.Va. (**M**)

Dula, Arthur M., Photographic Engineer, Engineering and Technical Div., Signal Corps. **Mail:** 505 East Westmoreland Rd., Falls Church, Va. (**A**)

Duncan, Charles B., Sound Engineer, Standard Theatre Supply Co. **Mail:** 219 South Church St., Charlotte, N.C. (**M**)

Golan, Joseph C., Superintendent, Production, Eastman Kodak Co. **Mail:** Huntington Hills, Rochester 9, N.Y. (**M**)

Gordon, Alan, Designer and manufacturer of photogrammetric equipment, Gordon Enterprises. **Mail:** 5362 North Cahuenga Blvd., North Hollywood, Calif. (**M**)

Hockman, Lt. Charles N., Director, Motion Picture Unit, University of Oklahoma. **Mail:** 2d Photographic Sq., c/o 548 Recon. Tech. Sq., APO 328, c/o PM, San Francisco, Calif. (**M**)

Kayfetz, Victor F., Producer, Victor Kayfetz Productions, Inc. **Mail:** 130 E. 56 St., New York 22, N.Y. (**M**)

Keen, Charles Y., Engineer, RCA Service Co. **Mail:** 209 Lippincott Ave., Riverton, N.J. (**M**)

Kilbrith, Donald Wilson, Radio Engineer, International Broadcasting Div., U.S. Department of State. **Mail:** American Embassy, Manila, APO 928, c/o PM, San Francisco, Calif. (**A**)

Klingenstein, Paul, Executive, Kling Photo Supply Corp. **Mail:** 235 Fourth Ave., New York 3, N.Y. (**A**)

Kuzmanov, Alexander, City College of New York. **Mail:** 20 W. 26 St., New York 10, N.Y. (**S**)

Libberton, John A., Motion Picture Production Supervisor, Foote, Cone & Belding. **Mail:** 3827 Alta Vista Ter., Chicago, Ill. (**M**)

Mahler, Joseph, Research Physicist, American Optical Co. **Mail:** 52 Old Road, Westport, Conn. (**A**)

Marshall, Derek, Motion Picture Supplies, Ltd. **Mail:** 17 Linden Court Apts., St. John's, Newfoundland, Canada. (**A**)

Mason, Curtis W., Chief Engineer, KFI-TV, Earle C. Anthony, Inc. **Mail:** 141 North Vermont Ave., Los Angeles 4, Calif. (**M**)

Ohba, Saburo, Electrical Engineer. **Mail:** 756 Yukigaya-madu' Ohta-Ku, Tokyo, Japan. (**M**)

Rabinovitz, Jason, Motion Pictures and Television, United Paramount Theatres, Inc. **Mail:** 1501 Broadway, New York 18, N.Y. (**A**)

Schantz, Joseph A., Technologist (photographic chemistry), U.S. Naval Photographic Center. **Mail:** 2508 North Granada St., Arlington, Va. (**A**)

Shaaber, Maurice A., Maintenance Supervisor, Florida State Theatres, Inc. **Mail:** 2815 Grand Ave., Jacksonville, Fla. (**A**)

Shelton, Edward E., First Lieutenant, Signal Corps Photographic Center. **Mail:** 7 Hunt La., Levittown (c/o Hicksville PO), N.Y. (**A**)

Streiffert, John G., Physicist, Eastman Kodak Co., Bldg. 59, Kodak Park, Rochester, N.Y. (**A**)

Strom, David E., Sales Manager, Text-Film Dept., McGraw-Hill Book Co. **Mail:** Blackwood La., Stamford, Conn. (**A**)

Subach, Albert C., Vice-President and Treasurer, Optomechanisms, Inc. **Mail:** 956 N. Third St., New Hyde Park, Long Island, N.Y. (**M**)

Swanstrom, Carl, Television Producer. **Mail:** 7657 Melrose Ave., Hollywood 46, Calif. **(M)**

Thoma, Reinhard A., Motion Picture Technician, Bell & Howell Co. **Mail:** 1046 Hollywood, Des Plaines, Ill. **(A)**

Unger, William H., Executive and Secretary, Elliot-Unger-Elliot Motion Pictures, Inc. **Mail:** 50 King St., New York 14, N.Y. **(M)**

Walker, Frederick Robert, District Sales Manager, Broadcast Equipment, General Electric Co. **Mail:** 1817 Midwick Dr., Altadena, Calif. **(M)**

Wightman, William W., Electrical Design Engineer, Bell & Howell Co. **Mail:** 6743 South Wentworth Ave., Chicago, Ill. **(M)**

CHANGES IN GRADE

Dunn, Linwood G., Special Effects Cameraman, RKO-Radio Pictures. **Mail:** 2000 North Berendo St., Hollywood 27, Calif. **(A)** to **(M)**

Elmer, Carlos H., Photographic Laboratory Supervisor, U.S. Naval Ordnance Test Station. **Mail:** 410 B Forrestal St., China Lake, Calif. **(A)** to **(M)**

Freund, Karl, Cinematographer, Photo Research Corp. **Mail:** 15024 Devonshire, San Fernando, Calif. **(A)** to **(M)**

Chemical Corner

Edited by Irving M. Ewig for the Society's Laboratory Practice Committee. Suggestions should be sent to Society headquarters marked for the attention of Mr. Ewig. Neither the Society nor the Editor assumes any responsibility for the validity of the statements contained in this column. They are intended as suggestions for further investigation by interested persons.

Chamois Fabric "X-Lint" is a fabric impregnated with "Hycar" latex which has all the properties of chamois but wears longer and, the manufacturer states, is unaffected by chemicals ordinarily harmful to chamois. "X-Lint" does not have the ragged ends and thin spots of chamois. The manufacturer of this product is Loren Products Corp., 101 West 31st St., N.Y. 1, N.Y.

New Idea in Filter Cloths Dynel filter cloths are made of acrylic fibers and are claimed to be superior to most filter materials because they are supposed to have good dimensional stability, are mildew-proof, easy to clean and nonblinding. Inquiries are directed to The Filtration Engineers, Inc., Newark, N. J.

Task of Making Fixer Greatly Simplified The L. B. Russell Chemicals, Inc., 60 Orange St., Bloomfield, N.J., manufactures a single powder which, when dissolved in water, forms a complete, odorless acetic-acid, long-lasting fixer. This preparation is called Super-Fix. The company states that film processed in this fixer will wash easily because of the proper adjustment of the pH and will have a well-hardened emulsion. Furthermore, the hypo which is used here is dehydrated, resulting in great reduction of bulk. This fixer powder eliminates the use of hypo crystals, acetic acid and all the other heavy fixer chemicals. This should be of interest to the smaller laboratory.

Floor Refinishing "Plastic Rock" makes a perfectly new, durable floor in forty-eight hours. It bonds well to concrete, wood and steel. It also is slipproof and fire resistant. The vendor is United Laboratories, 16801 Euclid Ave., Cleveland, Ohio.

Insect and Pest Control U.S. Industrial Chemicals has developed a new type of insecticide during World War II which they call "Lindane." It is claimed to be one of the most effective modern chemical insecticides. "Lindane" is effective against a wide variety of insects and is harmless to humans. The address of the manufacturer is 60 E. 42 St., New York 17, N.Y.

Corrosion-Proofing With a New Galvanizing Compound "Zinc-Rech" cold galvanizing compound produces an electrochemical reaction which deposits zinc on steel or iron surfaces, thereby galvanizing them. It can be applied by dip, spray or brush. Inquiries are directed to The Chase Chemical Co., 40 W. 29 St., N.Y. 1, N.Y.

Motion Picture Film and the Weather In the *Heating, Piping and Air-Conditioning Journal*, vol. 22, H. C. Brush, in his article "How humidity and temperature affect motion picture film," describes some interesting relations between temperature and relative humidity and various physical properties of film such as buckle, curl, shrinkage and brittleness. The influence of the atmospheric conditions on dust control, static, and storage of film is also considered.

New Idea for a Small-Capacity Water Filter A small water filter employing anthracite coal as a filtering medium is described in an article, "Fotopak water filter for finishers," in *Photo Developments*, vol. 24. The unit has a capacity of 100 gal/min, and no filter cones are needed.

Dye-Coupling Developers as Toners Since the use of uranium nitrate for the toning of motion picture film has been discontinued, it is difficult to duplicate the color with other toners. It is possible now, however, to achieve similar, and perhaps an even wider range of, tones by the use of dye-coupler developers. In this process the highlights are left entirely free of stain. The method is described in *The Photo Lab Index* as well as in many other such reference books. The chemicals are obtainable from The Eastman Kodak Co., Rochester 4, N.Y. The F. R. Corp. has marketed such a toner-developer under the name of "Develochrome." It is described in *Photo Trade News*, vol. 14, Sept. 1951, in an article by G. Steans.

Keep Out the Fire Weldwood Fire Doors have good insulating qualities for maintaining low temperatures in the protected areas. In a recent test the temperature of an exposed face of Weldwood Fire Door stayed down to less than 400 F after a 1-hr exposure to flame compared to 1000 F and 800 F for other fireproof doors. This product is marketed by U. S. Plywood Corp., 55 W. 44 St., New York 18, N.Y.

Watch Out for Old Film Valuable data on the subject of the composition and combustibility of nitrate film is discussed in the article "The anatomy of nitrocellulose film," by R. A. Mitchell and published in *The International Projectionist*, Feb. 1948. When nitrocellulose film decomposes it gives off gases which are inflammable and are the cause of so-called celluloid explosions. The emulsion helps somewhat to slow down the combustion. The emulsion leaves a black ash and gives off harmful fumes.

Temperature Control Device for Experimental Darkroom Hanney and Waldram, in an article, "Controlled temperature equipment for the experimental darkroom," in *The Photographic Journal, Section B*, July-August 1951, describe a thermostatically controlled water bath which keeps solution bottles at a temperature of 0.2° and which maintains a stainless-steel developing dish at the same temperature by a water jacket. Safety devices are also described for the protection of the equipment which is left unattended.

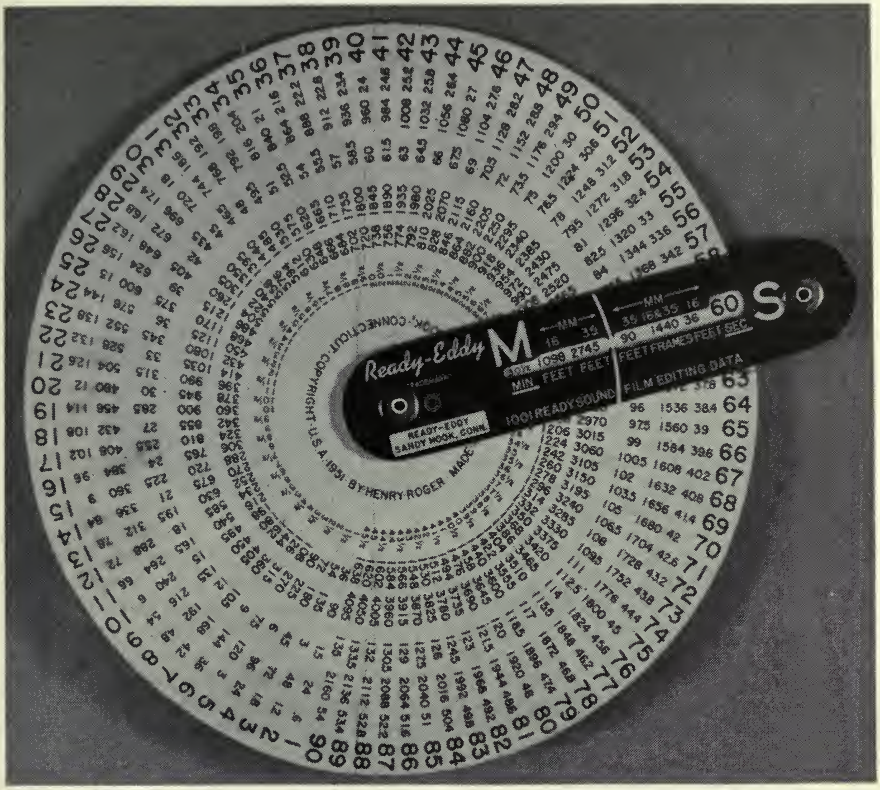
Back Issues of the Journal Available

The issues of May 1946, August 1946, February–July 1947 and September 1947 to date are available at $0.75 per copy from Robert G. Ellhamer, Box 2549, Hollywood Station, Los Angeles 28, Calif.

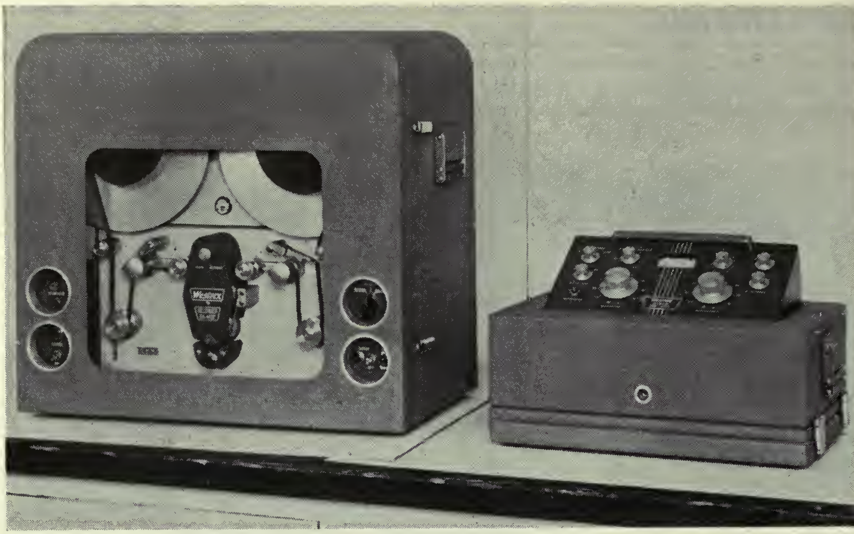
A set of Journals from October 1938 to the present date, except for the June 1939 issue, is available at $75.00 for the lot, from Harry Hollander, 21-36—77th St., Jackson Heights, L.I., N.Y.

New Products

Further information about these items can be obtained from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.



Ready-Eddy is the name given a new computer for sound film editors by its inventor, Henry Roger of Sandy Hook, Conn. It provides, with a turn of the wheel, correlated data regarding footage, projection time in seconds and minutes, number of frames per foot and per second, and equivalents of 16-mm and 35-mm film. One side of Ready-Eddy shows an "F" scale, representing feet, on the circumference of the disk, with four inner bands, two indicating seconds and number of frames for 35-mm film and the next two indicating the same for 16-mm film. The opposite side of the disk has two scales for time. On the periphery, "S" for seconds relates to three adjoining bands indicating feet of 16-mm film, number of frames of both 16-mm and 35-mm film (in this case the same for both) and feet of 35-mm film. Scale "M" for minutes starts from the inside and is subdivided into half-minutes of projection time. The two adjacent bands indicate the equivalent footages of 16-mm and 35-mm film, for from 1 to 45½ min. The inventor expects Ready-Eddy to be handy for television as well as motion picture editors. It is pocket-size, made of plastic, and costs $2.00. A plastic carrying case is $.50 extra.



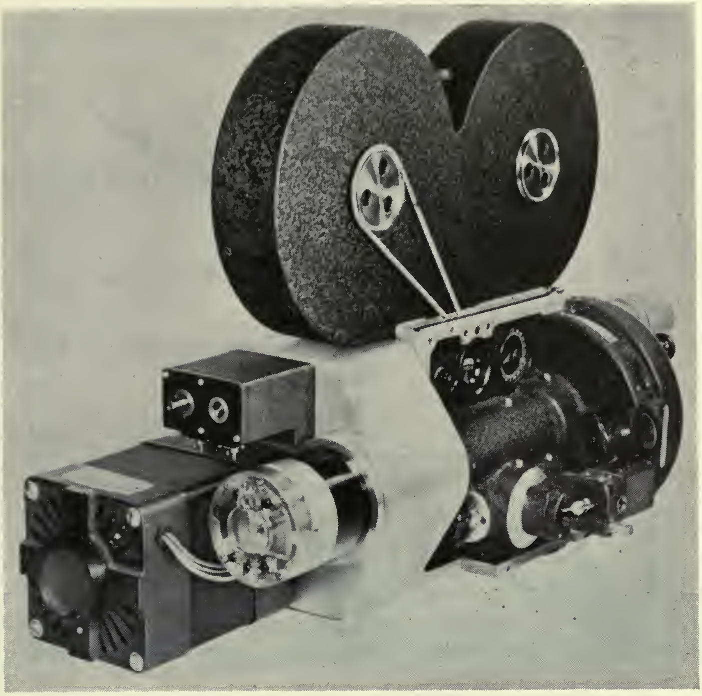
The 1000 Series Portable Magnetic System now being introduced to the industry is a direct outgrowth of field experience with the earlier 1000 Series System previously described in the *Journal* for March 1951. The number of cases has been reduced to two as shown in the photograph, the two-position mixer being on the right and the recorder being on the left. The latter houses, in addition to the film pulling mechanism, the a-c power supply for the channel, the bias oscillator and the film monitor amplifier.

New features of this system include two-way talkback equipment between the mixer and recordist, a talkback amplifier being provided in the recorder housing. Another new feature is a synchronizing bloop unit which records an audible signal when the recorder is up to speed on the magnetic film in synchronism with an optical bloop in the associated photographic camera.

The system operates from 115 v, single-phase, 50- or 60-cycle a-c supply, provision being also made for motor operation from 220 v, 3-phase, interlock or multi-duty motor systems. Runback at normal speed is provided. The power drain for the electronic components is somewhat less than 100 w and a 2-amp drain at 115 v is required for the single phase motor supply.

The weight of the complete system, including cables, is approximately 170 lb. The system is available for 35-, $17\frac{1}{2}$- or 16-mm operation. The track positions are in accordance with the proposed ASA magnetic track standards for 35- and 16-mm films. The recorder may also be used as a magnetic film reproducer, equalization being provided in the playback amplifier to give an essentially flat response from 50 to 8000 cycles when operating at 90 ft/min. By incorporating some pre-emphasis in recording on 16-mm film, a flat response to 6000 cycles may be obtained at the 16-mm speed of 36 ft/min.

Your Journals bound make a valuable permanent reference. Six issues constitute a Volume and should be bound with the special contents page (supplied beginning with Vol. 56) and index furnished with each June and December issue. For details of binding see page 702 of the June 1951 *Journal*.



The Maurer Servo-Sync Camera Drive, a new system for synchronized motion picture camera operation, providing greatly closer time synchronization than heretofore possible, is announced by J. A. Maurer, Inc., Long Island City, N.Y.

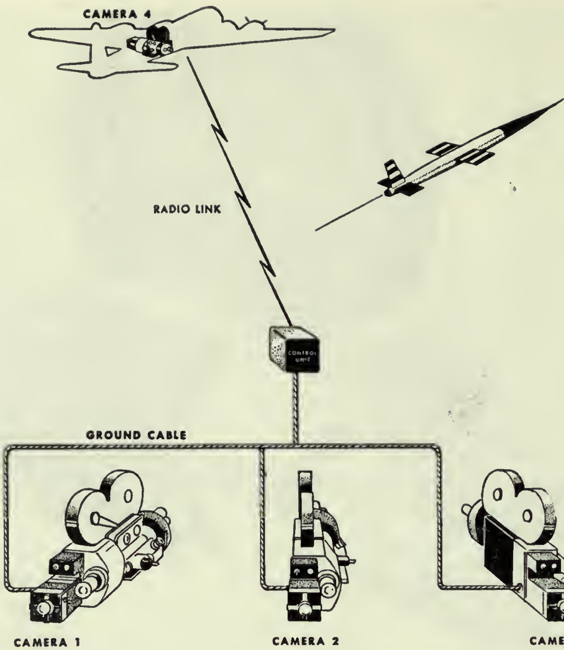
The system, known as the Maurer Servo-Sync Camera Drive System, was designed by Origins, Inc., Saybrook, Conn., and is manufactured by J. A. Maurer, Inc. It is designed to achieve a long-sought goal in scientific photography—dependable, consistent, and accurate operation of a series of motion picture cameras taking their pictures at the same time to close tolerance. Maximum possible deviation of shutter position in this system, which utilizes circular rotating camera shutters, is less than 1°, which at 12 frame/sec is equivalent to an accuracy of 23 microseconds. (A microsecond is one-millionth of a second.) As frame frequency increases, the angular accuracy remains essentially unchanged, while the time accuracy decreases. For example, at 50 frame/sec, the angular deviation is still approximately 1° and the time accuracy has increased to a maximum deviation of 35 microseconds. Due to the nature of the continuously rotating system, failures common to pulse-operated systems are eliminated. Patent rights are reserved.

The Servo-Sync Camera Drive System has been applied to a 35-mm motion picture camera of standard manufacture which uses interchangeable magazines having capacities of 400 and 1000 ft of film. The system is not limited to one camera type but is equally applicable for use with a large number of motion picture, scientific, and ribbon-frame cameras, and motion picture and process projectors.

The 35-mm camera system was developed for the Wollensack Optical Co., Rochester, N.Y.

Among the scientific and engineering applications for which this system will be utilized are: data recording, flight testing, missile tracking, ordnance evaluation, and most applications where two or more sources of information must be recorded at essentially the same time.

There is no practical limit to the number of cameras (projectors) that may be



synchronized by this method. An interesting use lies in three-dimensional studies where two geometrically oriented cameras are required for simultaneous recording. The system also has application in professional and television motion picture production where extremely close time synchronization of a number of cameras, projectors, or sound recording apparatus is required.

Statement of the Ownership, Management, and Circulation Required by the Act of Congress of August 24, 1912, as Amended by the Acts of March 3, 1933, and July 2, 1946 (Title 39, United States Code, Section 233), of *Journal of the Society of Motion Picture and Television Engineers*, published monthly at Easton, Pa., for October, 1951.

1. The names and addresses of the publisher, editor, managing editor, and business managers are:
Publisher, Society of Motion Picture and Television Engineers, Inc., 40 West 40th St., New York 18, N. Y.
Editor, Victor H. Allen, 40 West 40th St., New York 18, N. Y.
Managing editor, None.
Business manager, Boyce Nemec, 40 West 40th St., New York 18, N. Y.

2. The owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding 1 percent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a partnership or other unincorporated firm, its name and address, as well as that of each individual member, must be given.)
Society of Motion Picture and Television Engineers, Inc., 40 West 40th St., New York 18, N. Y.
Peter Mole, President, 941 N. Sycamore Ave., Hollywood 38, Calif.
Robert M. Corbin, Secretary, 343 State St., Rochester 4, N. Y.
Frank E. Cahill, Jr., Treasurer, 321 West 44th St., New York 18, N. Y.
No stockholders.

3. The known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)
None.

4. Paragraphs 2 and 3 include, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting; also the statements in the two paragraphs show the affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner.

5. The average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the 12 months preceding the date shown above was: (This information is required from daily, weekly, semiweekly, and triweekly newspapers only.)

VICTOR H. ALLEN, Editor.

Sworn to and subscribed before me this 17th day of September, 1951.

[SEAL] A. Ruth McCarthy
Notary Public, State of New York, No. 31-7790500, New York County.
(My commission expires in New York County, March 30 1952)

Stereographic Animation—

The Synthesis of Stereoscopic Depth From Flat Drawings and Art Work

By NORMAN McLAREN

With Appendix by CHESTER BEACHELL

A description is presented of various methods of producing a stereoscopic pair of motion pictures by photographing subject matter which in itself is two-dimensional and by using only standard monocular animation and optical equipment.

In 1950 the Festival of Britain asked the National Film Board of Canada to contribute two shorts for a program of stereoscopic and stereophonic films being shown at the Tele-kinema in London, with the specific request that the films be of an animated nature, to contrast with the "live" stereo films being made by the British themselves.

To our knowledge little had been done in three-dimensional animation. In 1939 the Loucks and Norling Studios pioneered with a very brief cartoon sequence in a film whose technique otherwise was a brilliant example of stereoscopic animation in the sense that solid objects were photographed using a stereo camera and stop motion; a description of this film was presented by J. A. Norling to this Society in 1939.*

Stop motion of a solid scene shot by a stereo camera is indeed one solution to the problem of the animated stereo film, and would recommend itself for all puppet and model work.

Our problem, however, was somewhat different, for we were concerned with the making of a stereoscopic film entirely from drawings, art work or other material which was flat in itself; in other words, we had to synthesize three-dimensional space from two-dimensional subject matter.

Since the subject matter to be photographed was flat, no special stereoscopic camera was needed, but simply the regular type of animation and optical

Presented on October 19, 1951, at the Society's Convention at Hollywood, by Norman McLaren, National Film Board of Canada, John Street, Ottawa, Canada.

*J. A. Norling, "Three-dimensional motion pictures," *Jour. SMPE*, vol. 33, pp. 612–634, Dec. 1939.

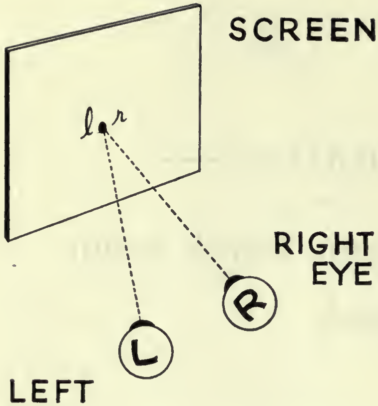


Figure 1

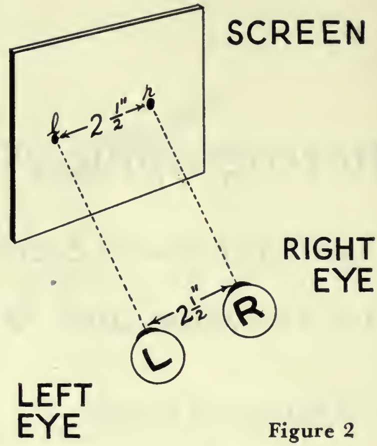


Figure 2

setup, the film for each eye being shot in succession.

Many possible technical approaches suggested themselves, the most obvious being that of adapting the standard cartoon technique by preparing two sets of drawings, a left- and right-eye version of each cell, with all the necessary parallaxes drawn into each cell. This technique, however, was discarded, due to limitations of time, staff and budget, in favor of several simpler methods which this paper will describe in detail.

Before doing so, it might be useful to review in simple language the principles behind the animator's approach to creating depth.

The Control of Depth by the Animator

In essence, this is done by controlling the amount of toe-in or toe-out of the spectator's eyeballs.

When a spectator looks at the screen in a normal flat cinema, the lines of sight from his left (L) and right (R) eyes are toed-in so as to meet each other at a point (lr) on the surface of the screen, as in Fig. 1.

Throughout the viewing of a normal flat film, the spectator's eyeball toe-in remains fixed. In viewing a stereoscopic film, however, this toe-in varies.

If our spectator, instead of looking *at* the screen, were to let his eyes drift and look away beyond the screen, staring at infinity, the lines of sight from his eyes (L and R) would become parallel, as in Fig. 2, and these lines would pass through the screen at two separate points (l and r).

Since the distance between the average spectator's left and right eye is $2\frac{1}{2}$ in., and since his lines of sight are parallel, the distance between the two points on the screen (l and r) will be $2\frac{1}{2}$ in. No matter at what distance from the screen the spectator is sitting, this will always be so.

Now, if our spectator were to look at an object located exactly halfway between himself and the screen, his lines of sight would cross each other at a point (lr) halfway between himself and the screen, as in Fig. 3, and the lines of sight, if projected beyond this point, would fall on the screen at two points, l and r.

Again, by simple geometry, we can see that the distance between l and r is $2\frac{1}{2}$ in., and that no matter what distance the spectator is from the screen, this will always be so; it is important to note that l and r are now switched, so that l is to the east and r to the west.

For the stereoscopic animator, these are three basic diagrams on which to

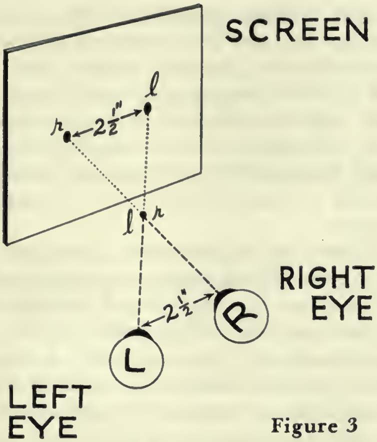


Figure 3

anchor all calculations of parallaxes. In designing a stereoscopic scene from flat drawings, the artist, if he wishes, let's say, a dot to appear on the surface of the screen, must have the left- and right-eye versions of the dot coincide precisely. For the dot to appear at infinity, there must be a $2\frac{1}{2}$-in. separation between the left- and right-eye images on the final screen, the left-eye image being on the left side of the screen and the right-eye image on the right.

For the dot to appear midway between the spectator and the screen, there must again be a $2\frac{1}{2}$-in. separation between the two images, but this time the left-eye image is on the right side of the screen, and the right-eye image on the left.

If the images are separated by progressively less than $2\frac{1}{2}$ in., the dot will be located progressively nearer to the screen than halfway, or nearer to the screen than infinity.

Separation of more than $2\frac{1}{2}$ in. for back-of-screen images has generally to be avoided as it places the object "beyond infinity," a condition which, due to the spectator's having to wall-eye, is almost as awkward to perceive as conceive. Separations of much more than $2\frac{1}{2}$ in. to bring the image closer to the spectator than midway can be used, but sparingly, in order to avoid eye strain for a certain percentage of the spectators

The animation artist, therefore, is not troubled by the major limitations, such as depth of focus, lens separation, lens toe-in, etc., which afflict the regular cameraman in stereoscopy. The stereoscopic world created by him is so calculated that no part of it will exceed the tolerable limits of parallax when projected on the screen, that is, so long as he knows the maximum size of screen on which his film is to appear. Knowing this size of screen, the amounts of parallax on its surface can be mathematically translated into amounts of parallax on the surface of the 35-mm film, and that, in turn, can be converted into amounts of parallax on the surface of the cell, cards or other art work.

The screen for which these Canadian films were designed was 15 ft wide, this being the requirement for the Tele-kinema in London, England, where two interlocked 35-mm projectors were lined up with their optical axes converging at the surface of the screen.

The pioneering work in the mathematics of three-dimensional projection by John T. Rule,* and more specifically an as yet unpublished paper by R. J. Spottiswoode entitled "The Determination of Stereoscopic Parallaxes in Animation," were used as a basis for calculating all parallaxes.

There follows a detailed account of the various production techniques used in the two films entitled *Now Is the Time* and *Around Is Around.*

Techniques Used in "Now Is the Time"

Parallax by movable cutouts in the art work. The opening scene of *Now Is the Time* is progressively built up of twelve planes of clouds, each flat in themselves, starting from the most distant and working forwards.

The most distant plane was located

*John T. Rule, "The geometry of steroscopic projection," *J. Opt. Soc. Am.*, vol. 31, p. 325, Apr. 1941.

at stereoscopic infinity. The nearest plane was located approximately halfway between the spectator and the screen.

The material prepared for shooting consisted of one black card 10 × 14 in. Clouds, varying in size from $\frac{1}{4}$ to 3 in. wide, were painted with white paint on small bits of black card. These were then stuck to the black card with double-sized tape in a series of horizontal rows varying in size from the smallest row in the center of the card to the largest at the bottom. The card was then placed under a standard animation camera and photographed on high contrast stock in such a way that the various rows of clouds were revealed in turn by a series of cross fades. This shooting was for the right-eye viewpoint; the card was then kept in the same position under the camera, but the lateral position of all the clouds on the card was changed. The cloud cutouts were moved in varying amounts either to the east or to the west to allow for the desired amount of parallax. Only one plane of clouds was left untouched, the one located on the surface of the screen. The parallactic shift was mathematically calculated for only the farthest and nearest planes, the rest being adjusted by eye — a relatively simple matter. The card with clouds was then shot again, following the same footage dope-sheet as before, to obtain the left-eye footage.

The sequence of appearing suns which follows the cloud sequence was done in the same way as the clouds.

Parallax by lens-shift in the optical camera. The little dancing man and the animation that grows out of it was done by a different method. With an ordinary writing pen and India ink, the action was drawn frame by frame directly on clear 35-mm machine leader (the usual animation stages of pencil sketches, inking, shooting and developing being short-circuited in the process of making the original negative).

The drawing was done from a mid-interocular viewpoint, that is, it was designed on the assumption that it would be representing a viewpoint mid-way between the final left- and right-eye viewpoints. The animated image itself was designed to remain at all times within a plane parallel to the cinema screen.

From this original hand-drawn negative, an optical print was made and loaded into the projector of a standard optical printer. A left- and a right-eye optical negative were produced in turn, the transverse action of the camera lens being used to create the required parallaxes. The amounts of parallax for the nearest and farthest planes were calculated mathematically. These amounts, split in half for each eye, were marked on the indicator controlling the transverse action of the lens on the optical camera, as movements to the left or right of zero position. The zero position itself represented the plane located on the cinema screen. A dope-sheet indicating the amounts of parallax required at key points in the animation was prepared. The dope-sheet for the right eye being the same as for the left except that, in shooting, the direction of transverse movement was reversed. The optical print was projected continuously at a speed of 160 frame/min, during which the artist, by glancing at the dope-sheet and watching the animation, turned the transverse control and created variable parallax in sympathy with the linear perspective of the flat drawing.

In cases where the parallax changed rapidly and in a varied fashion, the shooting was stopped periodically, or the camera run more slowly to secure greater control.

Combining the above material for the release printing. The left- and right-eye negatives from the optical camera bearing the animated images, and the left- and right-eye negatives from the animation camera

bearing the static backgrounds were then used as material for building up six parallel picture separation negatives (a yellow, cyan and magenta record for the left eye, and a yellow, cyan and magenta record for the right eye), for release color printing in English Technicolor.

Stereophonic animated sound track. Strictly speaking, the music of the film *Now Is the Time* should be classed as animation. This synthetic sound was produced by photographing patterns of black-and-white sound waveforms onto the sound track area of 35-mm film, using standard animation equipment and techniques.

The stereophonic system used in the Tele-kinema at the Festival of Britain employed four channels. To make the animated sound stereophonic, four identical prints were lined up parallel in a four-way, each representing one of the channels. Various notes were then blooped out of certain of the tracks, depending on which channel or channels the sound was desired to come from. This was possible because the animated sound was built out of small units each separated by small sections of unmodulated track.

Techniques Used in the Film "Around Is Around"

Parallax by double punch-holes on art work. The opening build-up of eight planes of stars was produced as follows:

The stereoscopic location of the eight planes was decided upon, and from this in turn were calculated the amounts of screen parallax, the amounts of parallax on the surface of 35-mm film, and the amounts of parallax for art work with a field 12 in. wide.

Eight standard animation cells (10 × 14 in.) were then punched with two sets of registration perforations; the distance between the two sets of punch-holes varied for each cell and depended on the amount of parallax required for the plane represented by each cell.

The plane representing the surface of the screen had only one set of punch-holes, there being an absence of parallax for that particular plane.

The art work (stars in this case, and representing no depth in themselves) was then painted on the eight cells. In order to prevent the final stereo scene from being asymmetrical, during the painting, the cells, when placed on top of each other, were registered for a mid-interocular viewpoint, that is, the mid-way points between the two sets of punch-holes were registered with each other.

In shooting, a standard animation camera and stand with registration pins and glass platten were used. The eight cells were not separated physically in space, but pressed close together under the glass platten. They were registered by the set of punch-holes for the right eye and shot once, then registered by the other set of punch-holes and shot a second time, for the left eye.

All static background material for the film *Around Is Around* was shot in this fashion.

Parallax by frame-stagger on the negative. The horizontal panning backgrounds of clouds and stars were cases in which the speed of travel of the various planes was so calculated that the dynamic parallaxes of a monocular panning shot gave rise automatically, when two identical prints were staggered by a certain number of frames, to the required binocular parallaxes for a stereo pair.

The monocular cloud and star panning shots were made by multiple exposures, the various planes, each with a different travel speed, being superimposed in the animation camera.

Assuming a one-frame stagger, the travel speeds for various planes were calculated. For example, for the infinity plane: The amount of parallax needed on the surface of the 35-mm film to locate a plane at infinity is known, therefore, the corresponding amount of parallax needed on art work of a given

field width can be calculated. This amount is the same as the amount of travel per frame required to locate this plane of the art work at infinity. Speeds progressively less than this will locate planes progressively closer than infinity, until an absence of any movement will locate the plane on the surface of the screen.

To locate subject matter *behind* the screen in a panning shot in which the subject matter is traveling eastward, frame 1 for the left eye should be placed opposite frame 2 for the right eye (L1 = R2). For westward traveling subject matter, R1 = L2.

If in the above shot with *eastward* traveling material the stagger is reversed, or the left- and right-eye films are switched (R1 = L2), then the planes are located stereoscopically between the surface of the screen (for the plane with no movement) and a point midway between the spectator and the screen (for the plane with maximum speed); similarly with westward traveling subject matter, when R2 = L1. To state this more briefly:

To locate planes in back of screen:

with eastward traveling subjects, L1 = R2;
with westward traveling subjects, R1 = L2.

To locate planes in front of screen:

with eastward traveling subjects, R1 = L2;
with westward traveling subjects, R2 = L1.

In the latter two cases, faster travel can be used for locating planes closer than halfway between the spectator and the screen; but in the former two cases, if faster travel is used the planes will be located beyond binocular infinity.

If a two-frame stagger is used and the same stereoscopic effect desired, the speed of travel of each plane has to be halved; if not, the total gamut of depth will be doubled.

A three-frame stagger will triple the depth gamut, unless the speeds of travel are divided by three, and so on.

In *Around Is Around* a seven-frame stagger was used for the white-on-magenta horizontal panning clouds, and a two-frame stagger in the last sequence of the film for the cyan stars on a blue background.

The frame-stagger technique was also used to create the stereo depth of all the linear animated images in *Around Is Around.*

These revolving images, Lissajous figures and other patterns were produced on an oscillograph, and a brief description of their means of production is given in an appendix to this paper.

A standard Bell & Howell camera was trained on an oscillograph, and the patterns photographed while in motion. The growth and change of the patterns were controlled by manually operating the control knobs on the oscillographic setup. The camera was run at 12 and also 8 frames/sec, rather than normal speed, to permit greater control of pattern modulation.

The movement of the patterns was kept predominantly horizontal, so that the monocular dynamic parallax would produce binocular parallax, when two identical prints were staggered as a stereo pair. The movement had to be slow enough to prevent the parallax between two adjacent frames from exceeding the tolerable limits of parallax for infinity. On the slower patterns a two-frame stagger was possible; on the quicker, a one-frame. Any vigorous vertical movement within the patterns was avoided, for this, due to the frame-stagger, would have created undesirable vertical parallax in stereo-viewing.

Parallax by frame-stagger plus lens-shift. Rotating patterns which travelled to and from the audience achieved their depth by combining frame-stagger and lens-shift techniques.

An optical print from the original

negative was shot twice on the optical camera, once for each eye, the parallax relating to the eventual to-and-fro movement of the pattern being introduced by camera lens-shift while shooting; the two resulting negatives were then staggered to produce the parallax relating to the rotational movement.

Conclusion

The above covers the various techniques used in the two films under review, and leaves untouched a number of others which were considered but not tried out.

Our particular choice of techniques was dictated by the setup at the National Film Board of Canada, and by our desire not to simulate reality (a thing which natural stereo photography can do most ably) but to create a new kind of reality more in keeping with the graphic method by which the films were produced. We were also interested in dispensing with some of the nonstereoscopic depth-assessing factors normally present in stereo films, such as interruption by opacity, light and shade, chromatic, hue, and tonal perspective, and to some extent diminishment (in the oscillographic patterns — which, however, have dynamic foreshortening) in order to discover to what extent and in what order the human mind relies upon these factors for depth information.

To sum up, our production experience would suggest that the major methods of introducing parallax into flat drawing and animation are probably:

1. stereo pairs of cards or cells, the parallax being drawn into the images,
2. double punching of single cards or cells,
3. movable cutouts,
4. movements of the horizontal panner under the animation camera,
5. horizontal panning or lens-shifting in the optical printer, and
6. frame-stagger on horizontal action shots.

Each method would seem to be effective for different purposes; obviously Method 1 has the greatest flexibility, and would recommend itself for cartoon work, particularly when combined with Method 2 for static backgrounds. On the other hand, for diagrammatic and cartographic animation some of the other methods may well be more suitable and economical, especially when the final visual is built out of several superimposed elements. At all events, it is quite safe to predict that combinations of all these methods will be useful for stereo animation, and that they will, in the future, become part of the technical ammunition with which the animated film will meet the challenge of stereoscopy.

Appendix: The Generation of Oscillographic Patterns in "Around Is Around"

There is no limit to the patterns obtainable on an oscillograph. This is easy to understand when we remember that a picture tube in a television receiver is a glorified oscillograph.

However, it was decided to keep the patterns relatively simple for two reasons:

(1) the difficulty of photographing an extremely complicated trace due to the low actinity of the fluorescent screen at high trace speeds, and

(2) the presence of vertical movement in the more complicated patterns.

The patterns themselves are mostly complete cycles — that is the sweep was sinusoidal — except for one or two patterns, notably the pillars. With a sinusoidal sweep the return trace is the same rate as the forward trace, and hence is visible, giving a closed loop.

There were never more than four component signals used to form any of the patterns in this film. The wave forms used were (a) sinusoidal, (b) square wave and (c) saw-tooth wave, including varying shapes and distortions

of the original waveforms. In some patterns varying degrees of phase shift were employed between vertical and horizontal deflection in order to produce such things as the revolving spring pattern.

The signal sources were: two audio-frequency signal generators with a range of 20 to 20,000 cycle/sec, one audio-frequency signal generator with a range of 7 to 70,000 cycle/sec and one square-wave generator with a range of 7 to 70,000 pulse/sec and 60-cycle line frequency.

A number of external and separate controls were set up in order that the size, movement, brightness and shape of the patterns could be changed and accurately controlled during any one shot. These controls were: (1) vertical micro gain, (2) horizontal micro gain, (3) mixing controls for the various waveforms so that they could be mixed on either or both sets of the deflection plates, (4) phase-shift controls set up so that they could be inserted in any signal source to either deflection system, and (5) a switch to rotate the pattern through 90° on the screen. This was necessary in order to keep the movement largely in the horizontal plane.

As the revolving movement in the patterns is a graphic presentation of the beat between two frequencies, it was necessary that all signal sources be as stable as possible. Instability caused varying rates of movement on the screen and if a pattern moved too fast, then the optical parallax, in final stereoscopic viewing, became too great. This was our biggest difficulty in that regulation had to be absolute in the power source, as any change in voltage in the oscillators or in the scope itself brought on unwanted movement. It was found that saturable core regulation transformers were a partial answer to the supply regulation problem; but, even with this, most of the shooting was done at night when there were no heavy intermittent loads on the a-c power.

Due to the low actinity of the phosphor used — the oscillograph tube was a 5LPI — it was necessary to shoot at varying frame rates depending on the complexity of the pattern. This was also an advantage as it permitted greater manual control of the figure during shooting. This brought on another difficulty, to slow the movement of the pattern so that the movement would be within reason when projected at 24 frame/sec. As an example: the base frequency is 60 cycle/sec. The beating frequency is the one-thousandth harmonic which is 60,000 cycle/sec. In order that the pattern will move, it is necessary to change one of the frequencies so that the beat frequency between them is 0.05 cycle/sec. This would mean absolute stabilization of the 60-cycle/sec signal and absolute stabilization of the second frequency at either 59,999.95 cycle/sec for clockwise rotation, or 60,000.05 for counterclockwise rotation. This meant that differences in frequency from one signal source to the harmonics of that frequency obtained from another signal source were as little as one-twentieth of a cycle per second. Crystal oscillators were impractical because a roomful of crystals would have been required.

The fireworks effect was achieved by charging the capacitor on the vertical positioning supply through a high resistance to a voltage greater than that required to center the beam and then bleeding it down to center position through another large resistance.

The most simple description of these patterns is that they are graphic presentations of the sums of the equations of various waveforms at any given instant in time.

Examination of Some Aspects of High-Quality Television for Motion Picture Industry Use

By BLAIR FOULDS and E. A. HUNGERFORD, Jr.

The day is coming when television will be a basic distribution medium for the motion picture industry. Equipment requirements for this purpose may well be different and more exacting than those currently accepted for television broadcasting. A review of the present state of the art, from a description of modern television equipment and consideration of some of the factors involved in adapting television for motion picture use, enables one to make an "educated guess" as to the potential needs of Hollywood in the light of what is now possible.

In *Variety*, dated Wednesday, September 19, 1951, there appeared a very significant article under the headline, "Arenas, Theatres in TV Battle." The article announced the intention of the International Boxing Club to operate its own circuit of big-screen television displays located in the boxing arenas throughout the country. Although Mr. Ned Irish has since called this "unsound," there is still evidence that ultimately this will take place. What better bolstering of the box office of local arenas could be imagined? After the usual preliminaries of the less-known fighters, in Pittsburgh, for example, the lights dim and a feature bout of national interest then comes from New York by television. This is the type of program they need to sustain boxing's own farm system.

The significance of this situation for the theater is quite clear. The motion picture industry was hoping to draw on another world, the sports world, to sustain box-office receipts in cities afflicted with the home television disease. This panacea may prove to be a will-o'-the-wisp. Fights and other big sporting events may well wind up on televised circuits in direct competition with the theater. In any case, they are too infrequent to be a major economic factor in theater television.

This may be a blessing in disguise. Let us see what would happen if fights, for instance, were to become commonplace fare. A typical fight audience is predominantly masculine, but the theater audience has always been a family audience. With fights an important part of the theater program, it is highly probable that the distaff side of the audience would be reduced. Although every Mr. Smith might want to see a fight, and even this is doubtful, certainly not every Mrs.

Presented on October 15, 1951, at the Society's Convention at Hollywood, Calif., by Blair Foulds and E. A. Hungerford, Jr., General Precision Laboratory, Pleasantville, N.Y.

Smith would want to see it, by television or otherwise. Perhaps overemphasizing such sporting spectacles in theater television may place the theater in real danger of changing the character of its audience.

Nor can the theater turn to Broadway for much assistance. Two years ago, economic studies showed quite clearly that when Broadway gets ready, it can syndicate its own plays to the hinterland by large-screen television and justify little theaters in major cities, also in direct competition with the motion picture theaters. And so it is with every phase of the entertainment industry. Television can help if used wisely, but it must be remembered that television is first and last a distribution medium with greater efficiency and speed than any known heretofore.

This fact bears repeating — television is fundamentally a new medium of distribution. It finds its application in many fields. But what of the motion picture–television relationship? Perhaps the action of the International Boxing Club makes that clearer.

The motion picture industry must depend upon its own great resources to use television wisely for its own interests in perfectly natural applications. Thus far the theater side of the business has shown the most foresight and has truly been aggressive in trying to understand and use television. Theaters have installed theater television with very little idea of just what programs they would be able to show on their screens. Sometimes they use it as little as two or three times a month. Yet they are gradually building up a network which will wield tremendous force and are creating the market for enterprising showmen to supply with suitable entertainment.

Curiously this is just the reverse of the television broadcast industry. There the program producers and the broadcasters have to hit the air first, hoping that their audience will buy receivers to look in on them. They build their distribution system by broadcasting first, providing the bait which tempts the public to buy. They have been phenomenally successful. Hollywood producers, on the other hand, sit still while their audience, the theaters, buy television sets to receive programs that do not exist. The courage of the theater man is certainly to be admired. Less can be said of the major studios in whose hands lie the greatest accumulation of creative talent in this country. Utilization of television by the motion picture industry must be effected by combined action of Hollywood and the theater.

How, then, can this be accomplished? It is late, but not too late, for producers to take an active part in television production. Imagine Hollywood putting on a revue with its many stars and feeding it live by television to a hundred theaters in the Los Angeles area. Very few people would stay home to watch broadcast television if such a bill of fare were available at their local movie houses. Couple this with a magnificent feature picture in color. Here is an entertainment combination hard to beat. Think of the Radio City Music Hall stage show fed simultaneously to a hundred eastern theaters to bolster the neighborhood box office. Television would be distributing something to the theaters that they haven't had since the days of vaudeville. And those were good days.

Our purpose as engineers is to be very certain that when Hollywood wishes to enter television production, the proper equipment will be ready.

It is clear that the big theater screen needs higher-quality television than is presently broadcast to the home. Yes, it should also be in color, but let us walk before we run. Even black-and-white television has not yet achieved the quality necessary for the motion picture industry. But today appropriate equipment is on the drafting boards and it can be manufactured.

Otto H. Schade has indicated in his several talks to the Society the specifica-

tions for high-quality television.* Messrs. Garman and Lee† have also outlined a system differing in details, but suitable for the purpose. Referring to Garman and Lee, 675 lines were recommended as the scanning-line pattern. The frame frequency was set at 24 to meet the custom of the motion picture industry where the prevailing situation of relatively low screen-projection brightness permits it. Some day the frame rate may go to 30 frame/sec and we shall see how that may happen.

When Hollywood begins to use high-quality television equipment to produce programs augmenting the feature-film programs of the theaters, there will be times when the economics of production will dictate that the television offering be recorded on film and distributed as such to theaters not yet equipped with television projection systems. So long as the theater has present-day film projectors installed, the 24-frame standard is mandatory. However, the television industry knows full well the undesirability of televising at 30 frames and recording at 24. Enough of the picture material is necessarily thrown away so that results are very unsatisfactory when horizontal panning is taking place. To eliminate this effect, 24-frame television may be a temporary necessity for the motion picture industry, assuming that technical difficulties of handling a 24-frame standard do not prove uneconomical. Thirty-frame television is really only desirable in the future when all projection equipment in theaters may have been replaced by electronic television projectors capable of black-and-white or color. Then, theater television can swing completely to 30 frames, films can be made at the new rate and video recordings can be made at the new rate.

Once standards are fixed, the next important step is the design of pickup apparatus, particularly the camera chains.

At present no television pickup equipment of suitable high quality is available commercially. It depends upon image tubes which are still experimental, and reproducing systems which are also in the development stage, but a start has been made. Laboratory experimentation with the 675-line 24-frame standard has been encouraging. Flying spot scanners have been constructed and operated at these standards. Design of a camera to operate both on 675/24 and 525/30 is under way and shows great promise. Such a camera would permit Hollywood producers the greatest flexibility. For example, video recording or closed-loop operations can be accomplished at 675/24, while standard pickups can be made to feed present theater equipments at 525/30.

While awaiting the ultimate, it will be useful to examine the newest television camera chain now being used by the television broadcasters. Many of the operational features were designed with the use by Hollywood producers very much in mind. Figures 1 through 7 show this camera chain.

Figure 1 shows the most modern camera chain available today. The design contemplates both studio and field uses. It consists of three basic pieces of equipment, the camera head, the camera control unit and the camera control unit power supply. The fourth unit shown is a remote-control unit permitting the control of focus and lens change from the camera control unit location or other remote position, as desired. The camera

---

*Otto H. Schade, "Image gradation, graininess and sharpness in television and motion picture systems—Part I, Image structure and transfer characteristics," *Jour. SMPTE*, vol. 56, pp. 137–177, Feb. 1951; "New system of measuring and specifying image definition," SMPTE Convention at New York, delivered on May 3, 1951; and "Requirements for a theater television system giving detail contrast equivalent to 35-mm motion pictures," SMPTE Convention at Hollywood, delivered on October 15, 1951.

†R. L. Garman and R. W. Lee, "A comprehensive proposal for a closed-loop theater television system," *Jour. SMPTE*, vol. 56, pp. 473–486, May 1951.

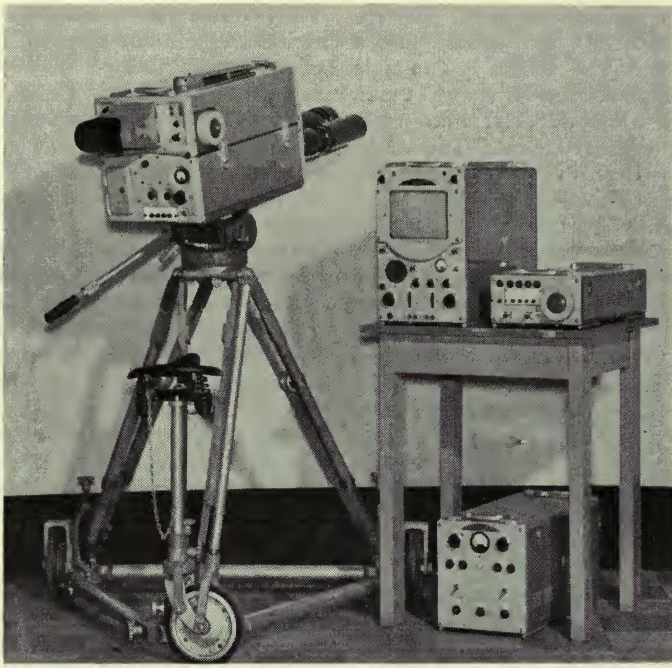


Fig. 1. Modern television broadcast chain for field and studio use.

is compact to permit maneuvering of many cameras simultaneously on the same studio set.

Since television is relatively complex and requires a certain amount of routine maintenance, this chain has been designed for maximum accessibility. Figure 2 shows the unit opened up, in which position it can still be operated normally while checks are being made.

Figure 3 is another view of this camera showing some of the controls. The operator's hand is on the focus knob which in this camera is the drive control of a servo system. In addition to providing easy remoting of the control, the circuitry provides the opportunity for ratio adjustment of the servo as a function of the focal length of the lens being used. Resistors built into individual lens mounts calibrate the servo so that 310° rotation of the focus control moves the image orthicon carriage not just so many inches, but a distance equivalent to the range from infinity to close up, matched to the focal length of the lens in use. Similarly, cams on the lens mount calibrate an iris reading system so that one meter reads the correct *f*-number setting of any action lens. Immediately below and to the left of this meter are push buttons, each of which is associated with a particular position on the turret. The turret mounts four lenses which can be of any focal length from two inches to twenty-four inches. Depressing the button associated with any particular lens immediately causes motor rotation of the turret to bring that lens into action by the shortest route.

Figure 4 shows the camera control unit where picture quality is adjusted. One significant advance is the two-way switch just beneath the lower right corner of the $8\frac{1}{2}$-in. picture tube. This switch controls the iris on the camera lens. Imme-

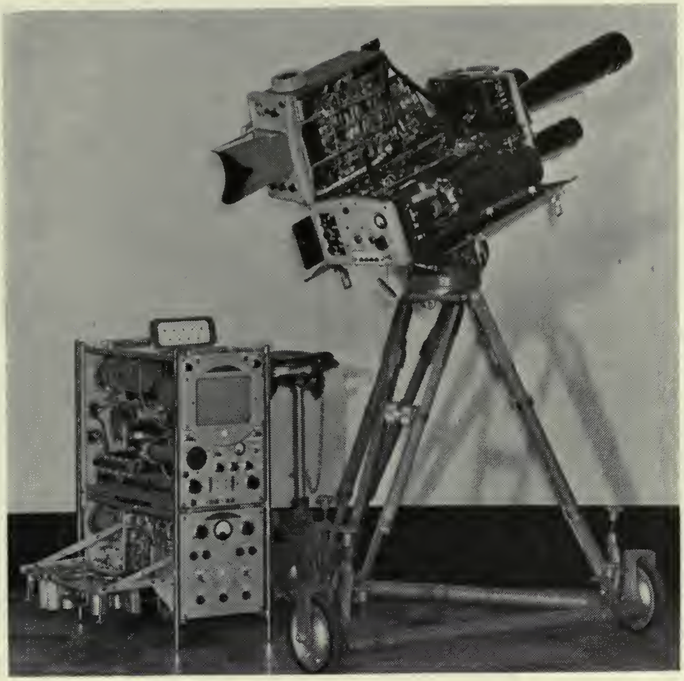


Fig. 2. Camera chain showing maintenance accessibility. Chain can be operated in this condition.

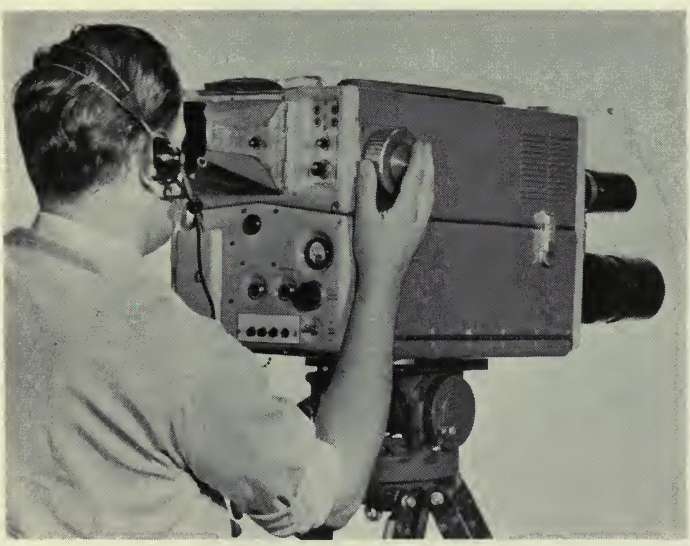


Fig. 3. Television cameral head, showing major controls.

diately adjacent is a meter which repeats the information on the camera meter, namely, the *f*-number setting. Just as with a film camera, the iris is most important in determining picture quality. If the image-orthicon tube is adjusted for proper operation, changing the iris is practically the only adjustment required over a fairly wide range of light. Now, for the first time, this control is available at the proper position so that the man responsible for picture quality can adjust the iris as he wishes.

In Fig. 5 is shown a synchronizing generator which is the nerve center of any television installation. This is a portable equipment and is significant principally for its compactness and stability. Binary counting is used, and all pulse widths are determined with reference to a delay line.

The switching unit is shown in Fig. 6. With a compact panel which can be swung into the unit for transport, this equipment provides for fades, lap dissolves and superimpositions, together with straight switching. Switch buttons are self-illuminating. The switching panel can be removed and extended as much as 5 ft for installation in proper console desks. As a companion piece, Fig. 7 shows the master monitor which views the output of the switcher, or previews dissolves or other effects. This team can handle as many as five cameras and two remote incoming circuits to provide the producer with adequate choice of shots.

The figures show the newest in television camera equipment, designed for the television broadcaster. The question is how closely does this equipment come to meeting Hollywood's requirements for motion picture applications? Whatever the technical standards pertaining to lines and frames, the physical form of the cameras can be much as you have seen or they can be packaged differently according to the dictates of the motion picture cameramen.

Several important design considerations should be discussed. Would Hollywood prefer optical viewfinders with their ability to see well beyond the photographed field, this in preference to electronic viewfinders which see essentially what the audience sees? This means duplicate lenses, of course, but perhaps it should be so. Does Hollywood want the cameramen to be in constant control of focus and lens change, or would it be better to have an assistant use a remote-control unit to hold focus and change lenses? This would give the cameraman the sole responsibility of maneuvering the camera to achieve the proper composition and balance.

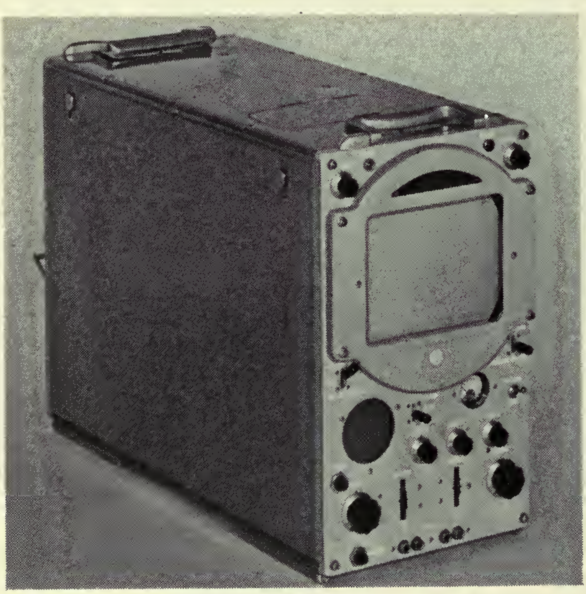


Fig. 4. Camera control unit. Note iris reading meter, and iris control switch slightly up and to the right.

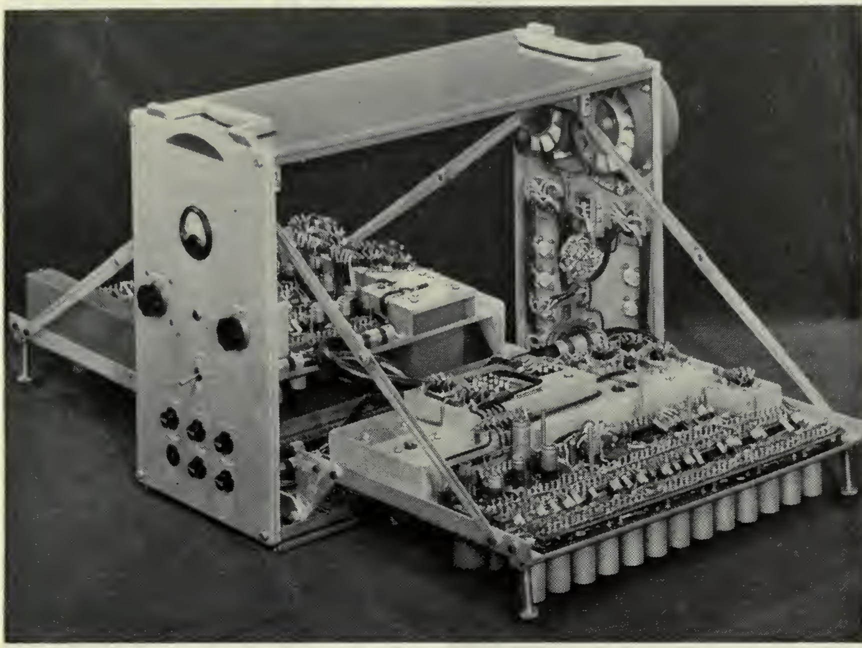


Fig. 5. Pulse generator, showing ease of accessibility. Generator can operate in this position. Power supply is built in. All chassis are standard relay rack size for studio mounting.

Fig. 6. Switching and mixing unit, showing switching panel ready for action. Panel folds into unit for transport.

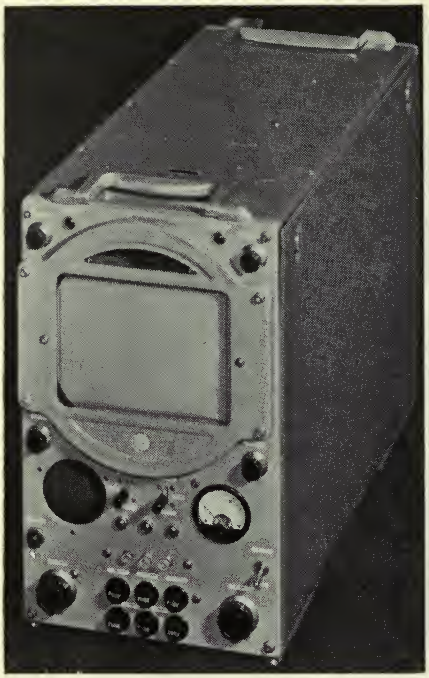


Fig. 7. Master monitor.

Or, to consider the camera control unit, what size of picture do Hollywood directors want to work with? What dynamic ranges in the system will they feel are necessary to achieve the required artistic effects? What optical effects are needed to meet the minimum requirements?

There are many more of these questions. But they are details. The important matter is the fact that the television manufacturer can now build equipment which will meet the requirements of the motion picture industry not only in regard to picture quality, but also as to flexibility and operational features for making the equipment most useful in the production of high-definition television for syndication to the theaters.

In addition to camera equipment for the live pickup aspect of television, machinery is now available for production to project motion pictures into a television system with a quality several times better than the current state of the art permits. Similarly, equipment for recording high-quality television signals is equally feasible. It remains only for the industry to tell the television manufacturers what is required. That will best be accomplished if the big motion picture producers take television into their own studios as the ally it can be, learn to use it, improve it and make it profitable. In so doing, they will probably find that some of the economies of television production may well be adapted to the motion picture industry, with resulting lower costs of production and greater output of standard product.

Within the motion picture industry are many men who are doing their utmost to understand television and its proper relation to their industry. They see the day when hundreds of theaters will play time and date alike, spreading the theater-load factor efficiently. Film and live production would be fed from central studios to the theaters. Television will be the distribution medium to the theaters — fast, efficient and sure. Already the theaters are beginning to build this distribution system on their own. How soon will the producer find ways and means to pump the finest of entertainment into this distribution system to the profit of all concerned?

Television should be used more and more by the motion picture industry. Its successful application depends, however, on the skill and talent of the producers and engineers within the motion picture industry. The next few years will undoubtedly see the entry of the production organization of Hollywood into television to properly cooperate with the distribution system being set up by the theater operators.

The Radial-Tooth, Variable-Pitch Sprocket

By J. G. STREIFFERT

A unique sprocket tooth whose driving face is a plane lying on a radius of the sprocket is used to improve longitudinal registration of the film over that obtained with conventionally shaped, curved-profile teeth. By supporting the film or films by means of an appropriately decentered drum while the films are in engagement with this sprocket, shrinkage accommodation is effected by virtue of the varying effective pitch of the sprocket. The variable-pitch effect also makes it possible to strip the film off the sprocket.

Calculated and measured flutter in sound prints and measured steadiness in picture prints made on a sprocket of this type in a 16-mm continuous contact printer are found to be substantially independent of film shrinkage and to be markedly better than in prints made on conventional printers.

It is well known that ordinary sprockets can impart uniform continuous motion to film only if the film pitch happens to be identical with the sprocket pitch and the tooth profile is one which clears the path of the perforation as the film engages and disengages the sprocket. If the film pitch does not match the sprocket pitch exactly, only one tooth will be driving at any one instant, and, at the time of transfer of load from one tooth to the next, the film motion will not be uniform.

Various expedients have been employed to reduce this type of nonuniformity. In some cases, brute force is used to stretch the film so that it matches the sprocket or matches another film on which it is to be printed. This usually requires the application of inordinately high tensions and/or pressure on the film so that excessive wear of the film perforations and driving members is likely to occur.

In other cases, various forms of what may be called "shrinkage-accommodating sprockets" have been proposed. Among the more promising of these sprockets have been those of Elmer,[1] Mechau,[2] and Chandler.[3]

The Elmer disclosure described a sprocket whose base diameter was determined by the pitch of the longest film likely to be encountered, whereas the tooth profile was a curve intended to allow film of maximum shrinkage to

Communication No. 1449 from the Kodak Research Laboratories, a paper presented on October 17, 1951, at the Society's Convention at Hollywood, Calif., by J. G. Streiffert, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y.

slip back uniformly with respect to the base of the sprocket as it stripped off the teeth. By this means, films of minimum and of maximum shrinkage would be driven without flutter. For intermediate values of shrinkage, the film would be driven for part of each pitch length of travel at the speed of unshrunk film, and for the remainder of the pitch length at the speed of film of maximum shrinkage. If the sprocket were designed for a shrinkage range of 1%, the peak variation in velocity would be 1.0% for all intermediate values of shrinkage. The rms deviation in velocity, commonly referred to as "flutter," would depend on shrinkage, because this determines the relative time the film is driven at each of the two speeds. For a shrinkage of 0.5%, the times would be equal, and the rms deviation would equal the peak deviation of 0.5%.

The Mechau proposal is shown in Fig. 1. The film is driven by a wafer-like sprocket and is supported by rotatable disks on either side of the sprocket. The disks are slightly larger in diameter than the base diameter of the sprocket and are eccentrically mounted relative to the sprocket. This provides a continuously increasing effective sprocket radius as the film passes through its engagement with the sprocket. The presumption is that the effective sprocket pitch depends on the effective radius. Film of any shrinkage is automatically driven in that region where the effective sprocket pitch most nearly matches the film pitch.

Since no mention was made of the manner of determining the optimum tooth profile, the Mechau specification was incomplete until a geometrical analysis was published by Chandler. His analysis follows these lines: Referring to Fig. 1, assume that the film is fed onto the sprocket at the point where the supporting disks are tangent to the base of the sprocket. The perforation will then describe an epicycloid curve relative to the sprocket base as it moves along the surface of the supporting member and away from the center of the sprocket. This epicycloid curve would be the correct tooth profile to drive unshrunk film. The sprocket and film would be in perfect mesh, i.e., each tooth would bear against each perforation. However, if the pitch of the film were either slightly shorter or slightly longer than that of the sprocket, then either the last tooth or the first tooth engaged with the film would be the only one which did any driving, and the film motion would be nonuniform.

To achieve the variable-pitch sprocket, it is necessary to modify the epicycloid curve, as shown in Fig. 2. When this is done, it can be seen that the effective pitch of the sprocket, i.e., the distance between teeth along the film line, will continually *decrease* as the film passes from the tangent point to the point of disengagement along the supporting drum or "stripper." The result is that any film whose shrinkage is within the range for which the sprocket is designed is automatically driven in that region where the effective sprocket pitch matches the film pitch.

Several of these variable-pitch sprockets have been tried, particularly in 16-mm contact and optical printers. While all of these sprockets handled the shrinkage range for which they were designed, picture steadiness and sound flutter were not as good as was believed possible, on the basis of the known precision of the film and of the mechanical parts involved.

It can readily be seen that accurate longitudinal registration of a film by means of a sprocket tooth which presents an inclined face to the edge of the perforation, depends on accurate control of the distance of the driven edge of the perforation from the center of the sprocket. For example, if the driven edge of the perforation were drawn down into the slot between the two supporting disks on either side of the sprocket because of friction of the film on the

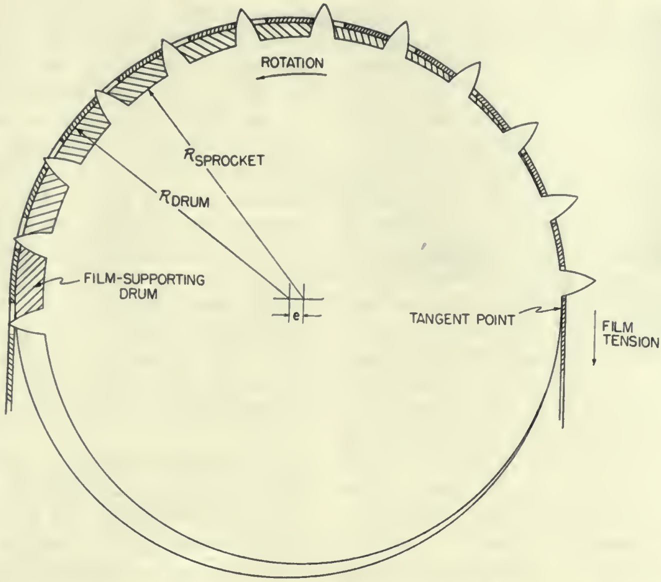


Fig. 1. Variable-pitch, shrinkage-accommodating sprocket assembly. Film of maximum shrinkage would be driven at extreme left; that of minimum shrinkage, at extreme right.

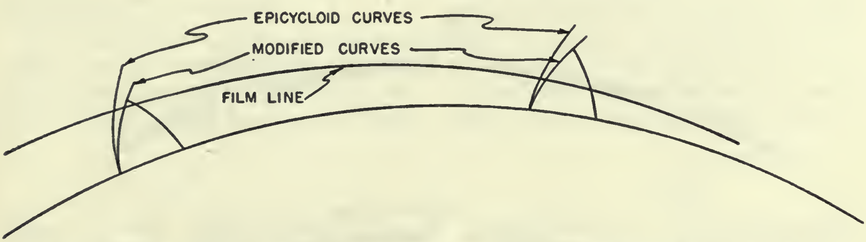


Fig. 2. Modification of epicycloid curve. Distance along film line between epicycloid curves is constant; distance between modified curves decreases as film moves outward on teeth.

teeth, then the film would not be correctly registered but would be advanced beyond its correct position. In order to avoid any such possibility, Sandvik and Chandler designed a printer in which the films were supported between the teeth as well as on either side. This was accomplished, as shown in Fig. 3, by recessing the sprocket inside the film-supporting drum and allowing the sprocket teeth to protrude through slots cut in the overhanging periphery of the drum. The drum was an integral member of pitch lengths greater in circumference than the sprocket and was engaged and driven by the sprocket in a gearlike manner. By this means, the film was supported directly under the point where the perforation bore on the tooth face and was pushed uniformly up along the profile as the assembly rotated.

Examination, by means of a microscope and stroboscopic illumination, of the action of the driven perforation

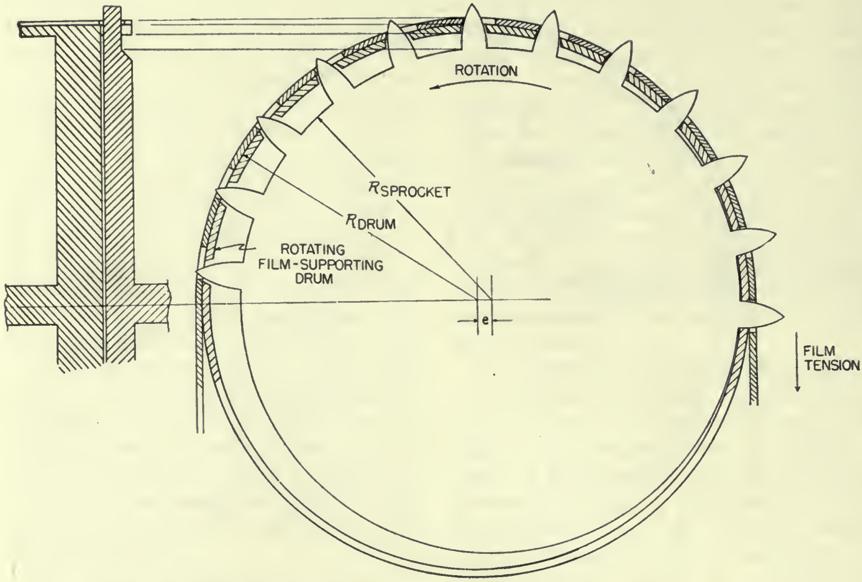


Fig. 3. Rotating stripper, variable-pitch sprocket. Stripper is driven by gear action of sprocket teeth in slots in edge of drum.

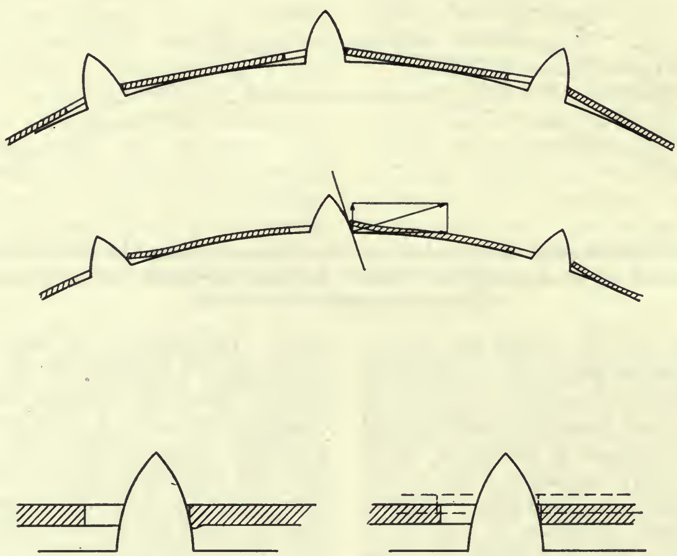


Fig. 4. Causes of poor longitudinal registration: inaccurate radial positioning of film on the teeth, and physical distortion and bending of film.

under the pressure of the driving tooth revealed that the film was not staying down against the drum, but was sliding up on the inclined face of the tooth by an amount varying from 0.001 in. to 0.003 in. Some of the causes for this are illustrated in Fig. 4. They include greater compliance and sharper bending of the film in the region of the perforation; distortion of the film because of the component of force normal to the film created by the driving force of the inclined tooth face; plastic deformation of the film under pressure; and nonuniformity of coefficient of friction from tooth to tooth and from perforation to perforation.

An attempt was made to reduce these errors by providing an external hold-down shoe of the same radius as the external surface of the film. While this resulted in substantial improvement, picture steadiness still did not meet expectations.

The Radial-Tooth Concept

With the above-outlined studies as a background, it was realized that for accurate longitudinal registration of the film the ideal driving face for the tooth would be one which lay on a plane normal to the film (parallel to the sprocket axis), as shown in Fig. 5A. Essentially this would mean that the driving face of each tooth would lie on a radius of the sprocket. A driving face of this type would have several important advantages. It would produce no radial component of force on the film, thereby eliminating outward distortion of the perforation from this cause. It would bear squarely against the full thickness of the film instead of against the sharp, somewhat irregular corner of the film. The position of the film on the face of the tooth would have very little effect on longitudinal registration of the film. Such a tooth would in many ways be substantially the equivalent of a registration pin in an intermittent mechanism.

Under normal circumstances, the difficulty with using a tooth with a radial driving face is that it is impossible to get the film off the teeth, because the involute curve described by the driven edge of the perforation as it leaves the sprocket tangentially cuts into the radial tooth, as shown by the dashed curve in Fig. 5B. This difficulty can be circumvented by combining the radial tooth with the variable-pitch concept.

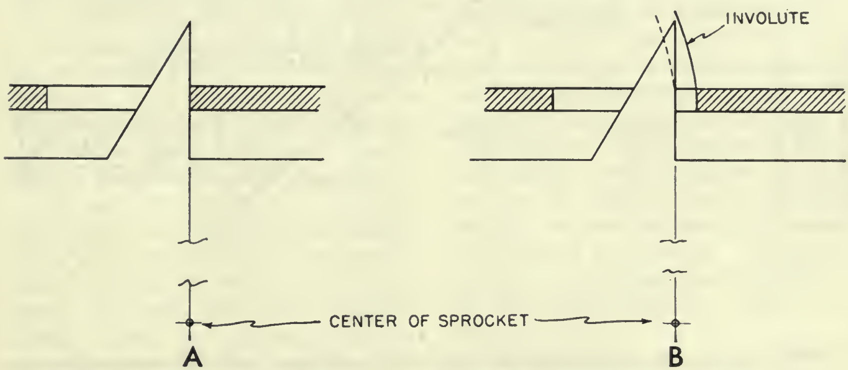


Fig. 5A. Ideal tooth with driving face normal to film plane. Registration essentially independent of position of perforation on tooth face; greatly reduces errors from film distortion and bending.

Fig. 5B. Interference of film with radial tooth at the stripping point. Provision must be made for advancing perforation relative to tooth so that film can be disengaged from sprocket.

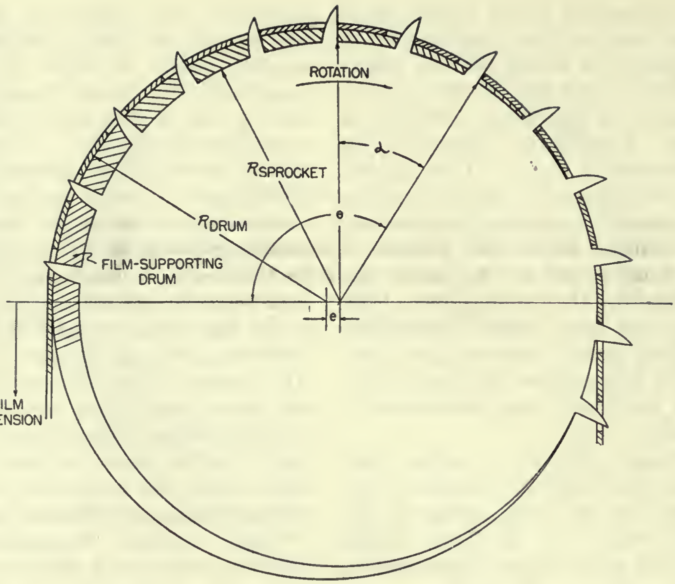


Fig. 6. The radial-tooth, variable-pitch sprocket.

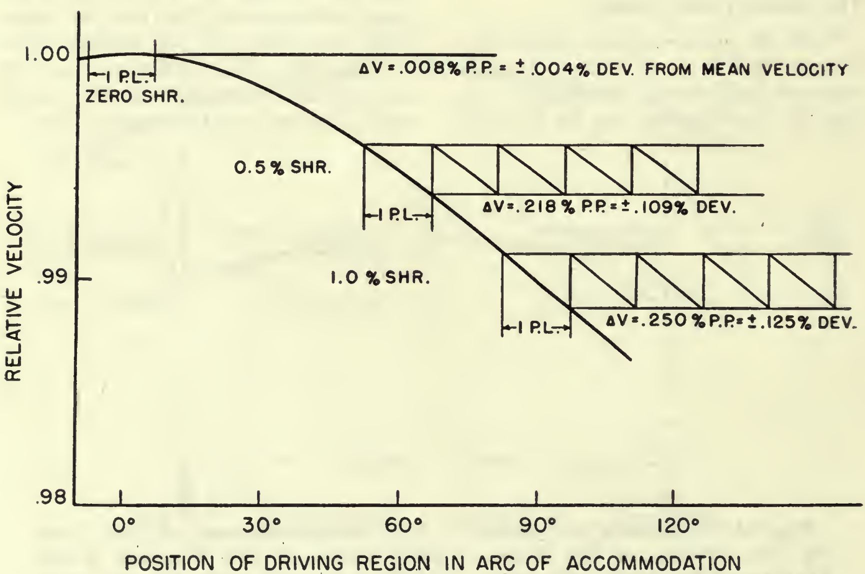


Fig. 7. Saw-toothed variation in film velocity caused by decreasing effective tooth velocity throughout arc of accommodation. P.L. = pitch length; P.P. = peak-to-peak.

In any variable-pitch sprocket, the change in effective sprocket pitch is the result of a changing effective tooth velocity along the film line. In the case of the radial-tooth variable-pitch sprocket, as shown in Fig. 6, the effective tooth velocity is a maximum when the effective sprocket radius is a maximum, i.e., when the film is at the tip of the teeth, and is a minimum when the effective radius is a minimum, i.e., when the film is at the base of the teeth. At some position between the points of maximum and minimum effective radius, the effective tooth velocity will be exactly equal to the lineal velocity at which film of a given shrinkage must be driven. To the left of this position, the effective tooth velocity will be greater than that of the film; and to the right, it will be less than that of the film. Thus, as a tooth travels through the arc of engagement, it is at first traveling faster than the perforation. Although its effective velocity is decreasing, it overtakes the perforation and drives for one pitch length, whereupon the next tooth takes over the driving function. The first tooth continues to decrease in effective velocity and falls behind the driven edge of the perforation so that there is again a clearance between the driving face of the tooth and the perforation.

This fact — that the tooth falls behind the perforation as it rotates beyond the driving region — provides the answer to the problem of getting film off a sprocket with radial teeth. The only requirement is that the shortest film which is to be accommodated, i.e., that film which requires the lowest lineal velocity, be kept in engagement with the tooth far enough beyond the region where it was driven to permit the tooth to fall far enough behind the perforation so that the film can be disengaged without interference, as shown by the solid curve in Fig. 5B. In practice, this means that the assembly must be designed so that the shortest film which is to be accommodated is driven at approximately the midpoint of the arc of engagement. The remainder of the travel provides for the clearance so that the film can be disengaged.

In Fig. 7 the effective tooth velocity is plotted as a function of sprocket rotation. Being a cosine function, the velocity decreases most rapidly when θ equals 90°. The change in velocity, ΔV, which occurs during one pitch length of travel, repeats as each new tooth takes over the driving function and results in the saw-tooth film-velocity curves shown in the figure. One of the problems in design is to make this change in velocity as small as possible. This is done by including as many sprocket teeth as possible in the accommodation arc.

Design Procedure

In general, two factors, namely, the shrinkage range to be accommodated and the height of the perforation, define the limits within which practical designs of radial-tooth, variable-pitch sprockets are found. The effect of each of these factors will be apparent in the design procedure outlined below.

1. Radius of Sprocket. Since the tooth velocity changes slightly during the driving interval, it is desirable that the sprocket be large so that there will be a large number of teeth in the accommodation arc and the change in velocity per pitch length will be small. On the other hand, as the sprocket size increases, the required tooth height increases and the permissible tooth thickness decreases, so that the ratio of tooth thickness to height becomes impractically small if the sprocket is too large. Diameters of 2 to 3 in. for 16-mm sprockets and 3 to 6 in. for 35-mm sprockets appear to be most practical.

The radius of a sprocket that will fit unshrunk film is given by:

$$R_0 = \frac{N \cdot P}{2\pi} - \frac{t}{2},$$

where N = the number of teeth, P =

the pitch of unshrunk film, and t = the thickness of film.

For a 25-tooth, 16-mm sprocket, this becomes

$$R_0 = \frac{25 \cdot 0.300}{2\pi} - \frac{0.0006}{2} = 1.1906 \text{ in.}$$

Since the percentage change in effective radius must be about twice that required to accommodate a given shrinkage range, the base radius of the sprocket must not be greater than:

$$R_s = R_0\left(1 - \frac{2s}{100}\right) = \left(\frac{NP}{2} - \frac{t}{2}\right)\left(1 - \frac{2s}{100}\right),$$

where s is the maximum shrinkage to be accommodated in per cent. For a 25-tooth, 16-mm sprocket to accommodate a maximum shrinkage of 1%, R_s = 1.1666 in.

2. Shrinkage Accommodation. The shrinkage range to be accommodated depends on the use to be made of the sprocket. In general, a sprocket to be used in a recorder does not need to accommodate as wide a shrinkage range as one used in a printer. In any case, the sprocket should be designed to accommodate a shrinkage range no greater than is absolutely necessary.

3. Arc of Engagement. If the film-supporting member is circular, as in Fig. 6, the arc of engagement is limited to a maximum value of 180°. Whether or not all of this can or need be used will be determined by other factors.

4. Arc for Accommodation of Shrinkage. Ideally, as much as possible of the arc of engagement should be devoted to accommodation of shrinkage while still leaving enough travel beyond the point where film of maximum shrinkage is driven, to permit that film to be disengaged. Since a mathematical determination of the optimal apportionment of these angles is complicated, it is easier to make the apportionment by trial. Actually, it has been found that very satisfactory designs can be realized if part or all of that portion of the arc of engagement to the left of the center of Fig. 6 is used for shrinkage accommodation, and as much as is necessary of the arc to the right of center is used for disengagement.

5. Radius of Drum, Decentering. The radius and the position of the film-supporting drum must be chosen so that the drum produces the required change in effective sprocket radius. If the first 90° of the arc of engagement is devoted to shrinkage accommodation, then the drum should have a radius equal to:

$$R_D = R_0\left(1 - \frac{s}{100}\right),$$

and the decentering would be:

$$e = R_0 \cdot \left(\frac{s}{100}\right).$$

For the 25-tooth, 16-mm sprocket,

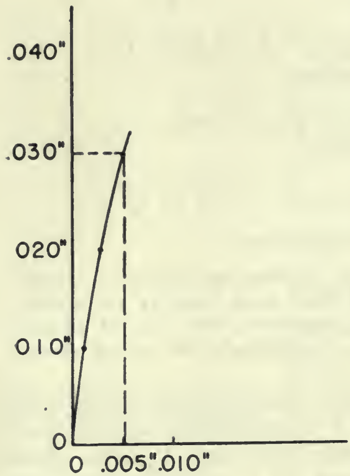
R_D = 1.1786 in., and e = 0.012 in.

6. Arc for Disengagement. The arc through which film of maximum shrinkage is required to travel beyond the midpoint of Fig. 6, before it can be disengaged tangentially, is determined by the involute curve and the height of the teeth.

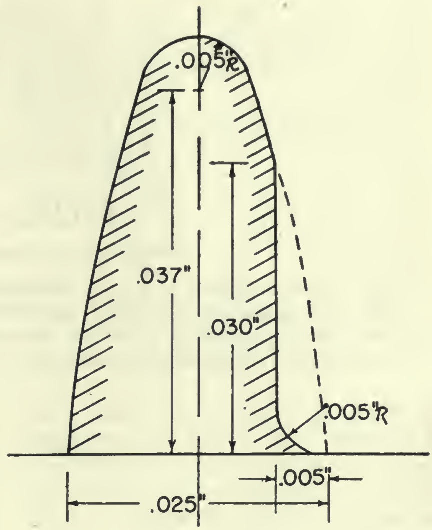
7. Involute Curve. In Table I are given coordinates of points which, when multiplied by the sprocket radius, give

Table I. Coordinates of Points on Involute Curve for Sprocket of Unit Radius

θ	x, in.	y, in.
2°	0.00002	0.00061
4°	0.00013	0.00243
6°	0.00040	0.00546
8°	0.00093	0.00970
10°	0.00182	0.01511
12°	0.00305	0.02169
14°	0.00484	0.02941



A



B

Fig. 8A. Involute curve for 25-tooth, 16-mm sprocket.

Fig. 8B. Tooth profile for 25-tooth, 16-mm, radial-tooth, variable-pitch sprocket.

the involute curve for that sprocket. The curve is plotted in Fig. 8A for the 25-tooth 16-mm sprocket.

8. Height of Teeth, h. Assuming that the arc of engagement equals 180°, in order for the tooth to protrude through one thickness of film at the extreme left in Fig. 6 where the effective radius is a maximum, the tooth height should be at least $2e + t$, where t is the film thickness. By marking this height on the involute curve, as in Fig. 8A, and by drawing a vertical line to the base, the distance which the perforation must be ahead of the radial tooth face at the tangent point is determined. For the 25-tooth sprocket, $h = 2e + t = 0.030$ in., and it is seen that a clearance, c, of 0.0046 in. must be provided between the perforation and the radial-tooth face before the film can be stripped off tangentially without interference.

9. Advance of Film of Maximum Shrinkage. The amount that film of maximum shrinkage will advance with respect to the tooth in traveling from the midpoint to the end of the arc of engagement will be essentially $A = e(1 - \cos \alpha)$. This must be equal to or greater than the clearance, c, computed above. If, in the case of the 25-tooth sprocket, A is made 0.006 in. to provide some margin, then $\alpha = 60°$.

10. Advance of Unshrunk Film. The amount that film of zero shrinkage will advance with respect to the tooth in traveling from the beginning to the end of the arc of engagement will be essentially:

$$A_0 = e(1.5708 + 0.01745\,\alpha - \cos \alpha).$$

In the present example, $\alpha = 60°$, so that unshrunk film will have advanced by 0.0253 in. by the time the stripping point is reached.

11. Thickness of Teeth, T. The thickness of the teeth cannot be greater than the difference between the height of the perforation and the amount that unshrunk film advances with respect to the face

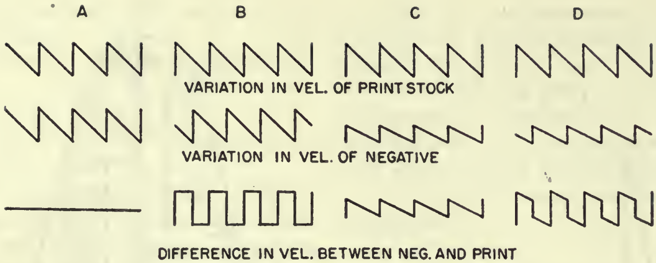


Fig. 9. Dependence of flutter introduced by printing operation on amplitude and phase of individual negative and print stock velocity variations: A — equal amplitude, in phase; B — equal amplitude, 180° out of phase; C — unequal amplitude, in phase; D — unequal amplitude, 180° out of phase.

of the tooth. The 16-mm perforation is 0.050 in. high, so that the tooth thickness, T, must not be more than $0.050 - 0.0253 = 0.0247$ in., in the present example. Actually, a value of $T = 0.020$ in. was used.

12. Tooth Profile. Apart from the required height of the radial face of the tooth and the permissible thickness at the base, the tooth profile is quite arbitrary. A suggested procedure is to cut an involute tooth of thickness $T + c$ at the base, and then cut the radial face on the tooth to a height of h and a tooth thickness of T at the base. Such a tooth is sketched in Fig. 8B. Actually, the radial face is never used below approximately the midpoint, where film of maximum shrinkage bears against it while it is being driven, so that the corner at the base need not be sharp but can be left rounded, as shown in the figure.

13. Theoretical Flutter. As was shown in Fig. 7, the effective tooth velocity is a cosine function of the rotation, and the change in velocity is most rapid when $\theta = 90°$. In this region, the percentage change in velocity during one pitch length of travel is given by:

$$\Delta V = s \sin \frac{360°}{N},$$

where s is the film shrinkage in per cent which is accommodated in this region, and N is the number of teeth on the sprocket. For the 25-tooth sprocket designed for a maximum shrinkage of 1%, the change in velocity would be 0.25%. This is the total or peak-to-peak change in velocity, and, since the change is almost exactly linear, the peak deviation from the mean velocity would be 0.125% and the rms deviation or theoretical flutter would be 0.072%. At lower values of shrinkage, the flutter would be less than this value, and at zero shrinkage ($\theta = 0°$) it would be substantially zero.

Sprockets for Printing

1. Shrinkage Range for Print Stock. In the foregoing discussion, consideration was given to the propulsion of only one film. In a contact printer, the print stock is at a greater radius than the negative by one thickness of film. In the present example, the film thickness is 0.5% of the sprocket radius, and therefore the pitch range for the print stock would be from 0.5% long to 0.5% short. Actually, in order to drive film of 0.5% stretch, it would be necessary to increase the height of the radial driving face of the tooth by one thickness of film, and this might require a reconsideration of the other design factors. If one is content with a pitch range of zero to 0.5% shrinkage for the print

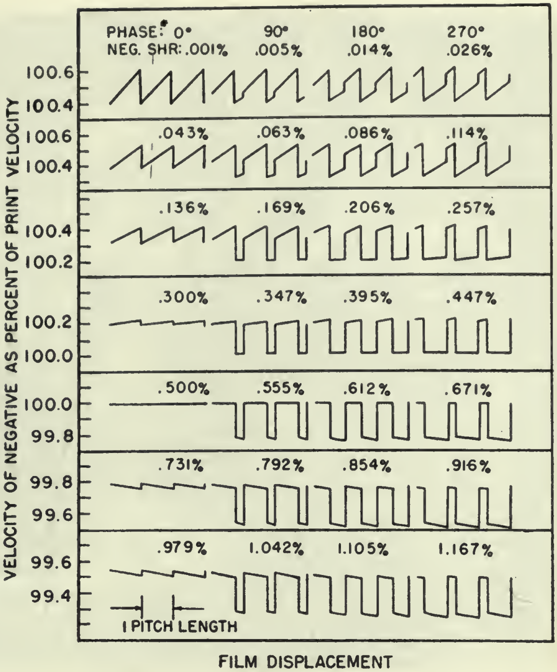


Fig. 10. Theoretical waveform of flutter introduced into print by printing operation as a function of negative shrinkage.
*** Phase of negative velocity variation relative to print stock velocity variation. Print stock shrinkage = zero.**

stock, no modifications whatever need be made in the sprocket. In optical printing, each film would be propelled by a sprocket especially designed for the shrinkage range it was required to accommodate.

2. *Flutter in Printing.* Theoretically, in either a contact or an optical printer, each film would experience a saw-toothed velocity variation, as explained earlier. Conceivably, these velocity variations could be of the same amplitude and exactly in phase so that the net velocity between the films would be zero at all times. This would occur in a contact printer, for example, when both films were being driven by the same tooth at every instant, and in that case the printing operation would theoretically introduce no flutter into the print. This condition is illustrated in Fig. 9A. If, however, the amplitudes and/or phases are not equal, as in Figs. 9B, 9C and 9D, then the instantaneous velocity difference will determine the flutter introduced by the printing operation.

In Fig. 10 are shown a family of theoretical print flutter waves for the 25-tooth, 16-mm sprocket when used for contact printing. The print stock is considered to have zero shrinkage, and the waveforms are shown for various negative shrinkages of from zero to 1.1% as the driving point for the negative changes by $\frac{1}{4}$-pitch-length (90°) intervals relative to that of the print stock. From the figure and from the data in Table II, it can be seen that the peak-to-peak flutter introduced in the print never exceeds the larger of the peak-to-peak velocity variations in the individual films. The worst conditions are those in which the individual velocity variations of the two films are out of phase by one-half pitch length (180°) and the amplitudes are substantially equal. In these cases, the flutter in the print is of substantially square wave-

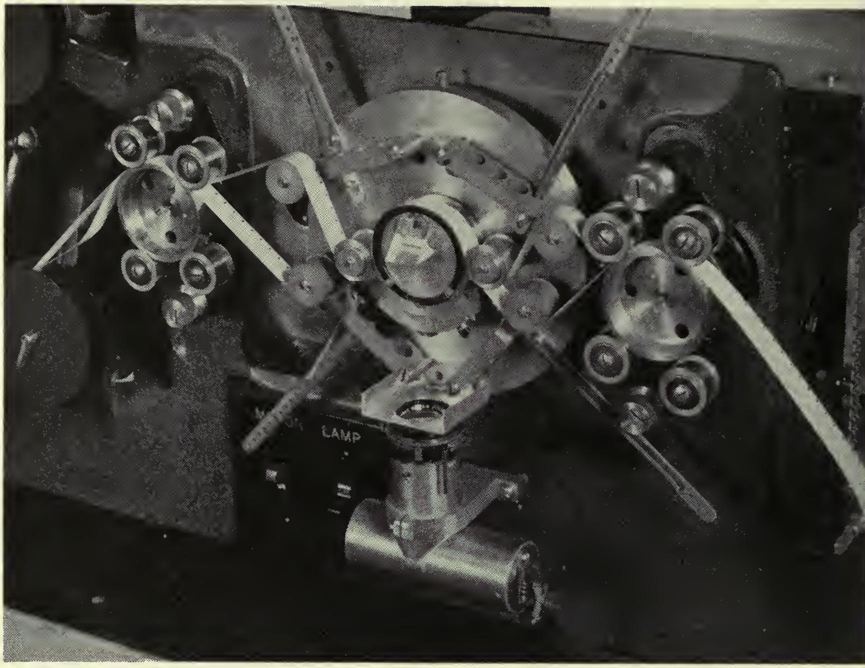


Fig. 11. Radial-tooth, variable-pitch sprocket assembly on experimental 16-mm printer.

Table II. Theoretical Flutter vs. Negative Shrinkage in 16-mm Contact Prints Made on a 25-Tooth Radial-Tooth Variable-Pitch Sprocket. Shrinkage of Print Stock, Zero

Phase angle, deg	Negative shrinkage, %	rms velocity deviation, %
0	0.001	0.059
180	0.014	0.072
0	0.043	0.042
180	0.086	0.086
0	0.136	0.029
180	0.206	0.108
0	0.300	0.008
180	0.395	0.102
0	0.500	0
180	0.612	0.116
0	0.731	0.014
180	0.854	0.124
0	0.979	0.020
180	1.105	0.125

form and the peak and rms velocity deviations are substantially identical and equal to 0.125%.

3. Picture Steadiness. It is readily apparent that picture unsteadiness introduced by a printer is not caused by differences in velocity which repeat every pitch length, but is caused by erratic differences in velocities which are unpredictable. Repetitive velocity differences only cause an undetectable vertical distortion of the image and possibly a slight loss in definition in local areas.

Experimental Contact Printer

An experimental 16-mm printer was modified to use a 25-tooth sprocket of the above design. Figure 11 is a photograph of the printer. The printing

sprocket is a thin wafer of tool steel. On either side are the decentered film-supporting drums. Feed-on and feed-off rollers are located so that the film has a wrap of 150° between tangent points. Tension rollers and arms are made as light as possible through the use of magnesium and are spring-loaded to keep the films against the driving faces of the teeth and to keep the films in good contact.

The sprocket itself was cut by using a special fly-cutter on a precision hobbing machine. The hub of the sprocket was provided with four adjusting screws so that it could be accurately adjusted for concentricity after it was mounted on the printer. Concentricity was checked in the manner illustrated in Fig. 12. The sprocket was rotated so that each tooth in succession rested against the end of a brass spring disposed normal to the radial-tooth face, while, diametrically opposite, the position of another spring substantially parallel to the tooth face was measured with a microscope. By this means, virtually all trace of eccentricity was eliminated. An ellipticity of approximately 0.0001 in. remained, about which nothing could be done.

The film-supporting members were made of tool steel, hardened, polished and chrome-plated. Negatives are cleaned and waxed frequently.

Since in a shrinkage-accommodating printer of this type slippage between the films is not eliminated but only made as uniform as possible, it is imperative that the exposing aperture be made as small as possible lengthwise of the film to avoid loss of definition. For example, if there is a difference in velocity of 0.5% between the two film surfaces, then in traveling past a 0.1-in. aperture the films would creep 0.0005 in., an amount which would theoretically obliterate a 7200-cycle wave on 16-mm film. In the experimental printer, a cylindrical lens was used to reduce the aperture to approximately 0.020 in.

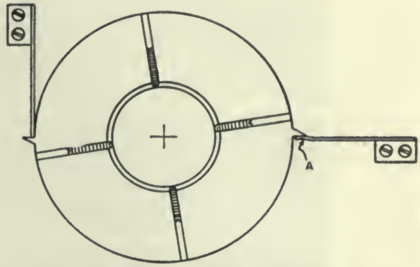


Fig. 12. Setup for adjusting concentricity of sprocket. Position of a point on spring at A is measured with a microscope normal to diagram.

Testing Procedure

1. Sound Tests. In order to test the effectiveness of the sprocket for printing sound, a series of flutter negatives was recorded on a high-quality, drum-type recorder on stock which had been perforated to a series of pitches to simulate films of from zero to 1% shrinkage. The negatives were exceptionally free from 24-cycle flutter, although some low-frequency disturbance was present. Since the printer would be expected to introduce principally 24-cycle and higher disturbances and no low-frequency disturbance, the flutter in the negatives and prints was measured using a flutter meter adjusted to read the flutter in the 10- to 300-cycle band only. A flutter-free sprocketless reproducer with a 15-in. viscously driven flywheel was used in reproducing the films.

In Fig. 13 are shown fluttergrams on the test negatives and in Fig. 14, those on a typical set of prints. Shrinkages indicated are those at the time of printing. Flutter percentages recorded on the charts are readings of a rectifier-type meter calibrated to read rms values on sinusoidal waves. The periodic variation in amplitude in the print fluttergrams is probably caused by the slight ellipticity in the sprocket.

In Fig. 15 is shown a set of flutter-

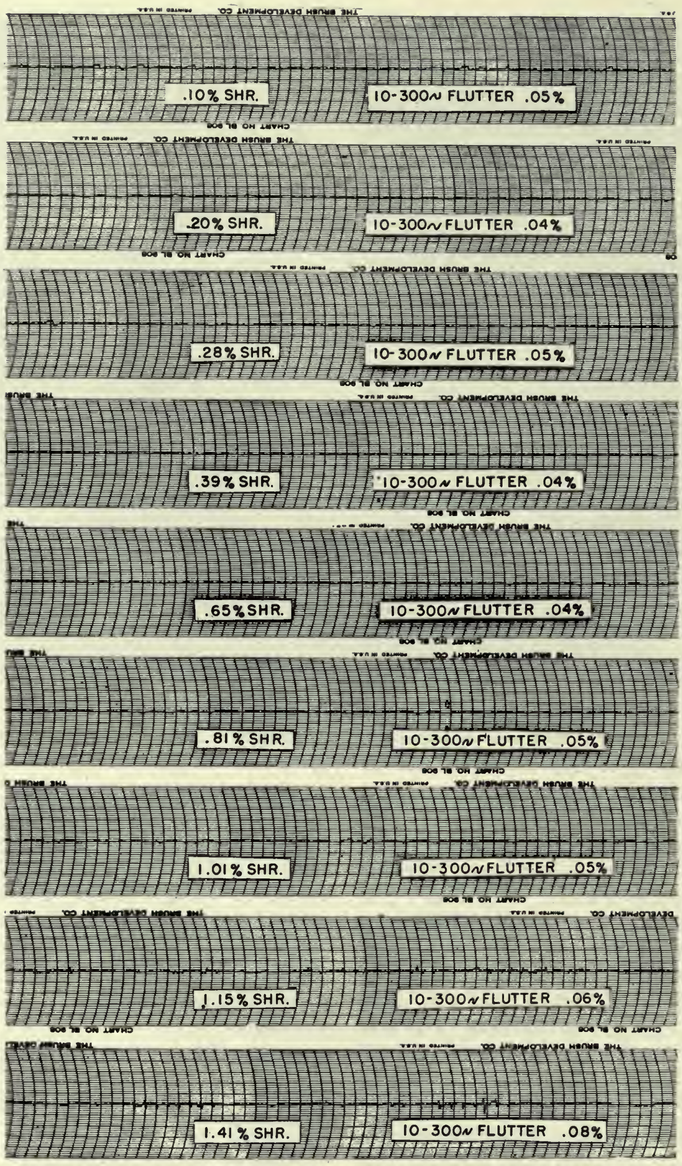


Fig. 13. Fluttergrams of 3000-cycle/sec flutter-test negatives.

grams on a similar set of prints made on a commercial 16-mm printer. The reduction in recorder sensitivity for the three prints from the negatives of maximum shrinkage should be noted.

2. Picture-Steadiness Tests. In order to test the printer for picture steadiness, a set of test negatives was exposed on a step-printer mechanism which could be used both as a camera and as a projector.

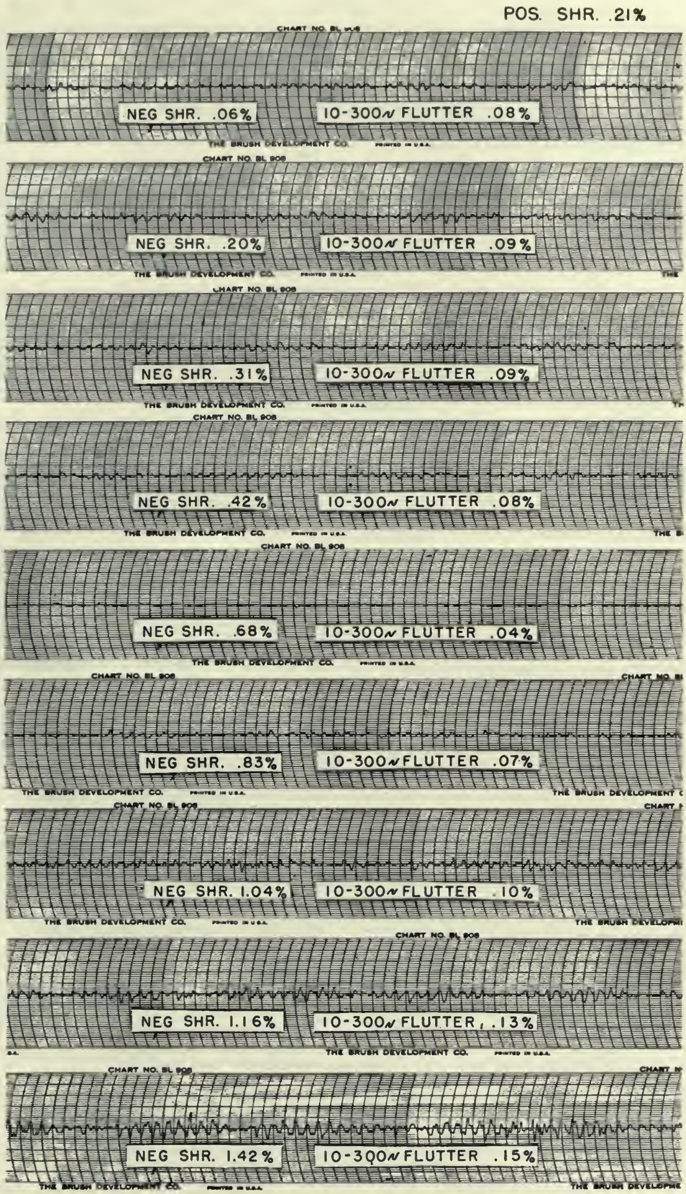


Fig. 14. Fluttergrams of contact prints made on radial-tooth, variable-pitch sprocket.

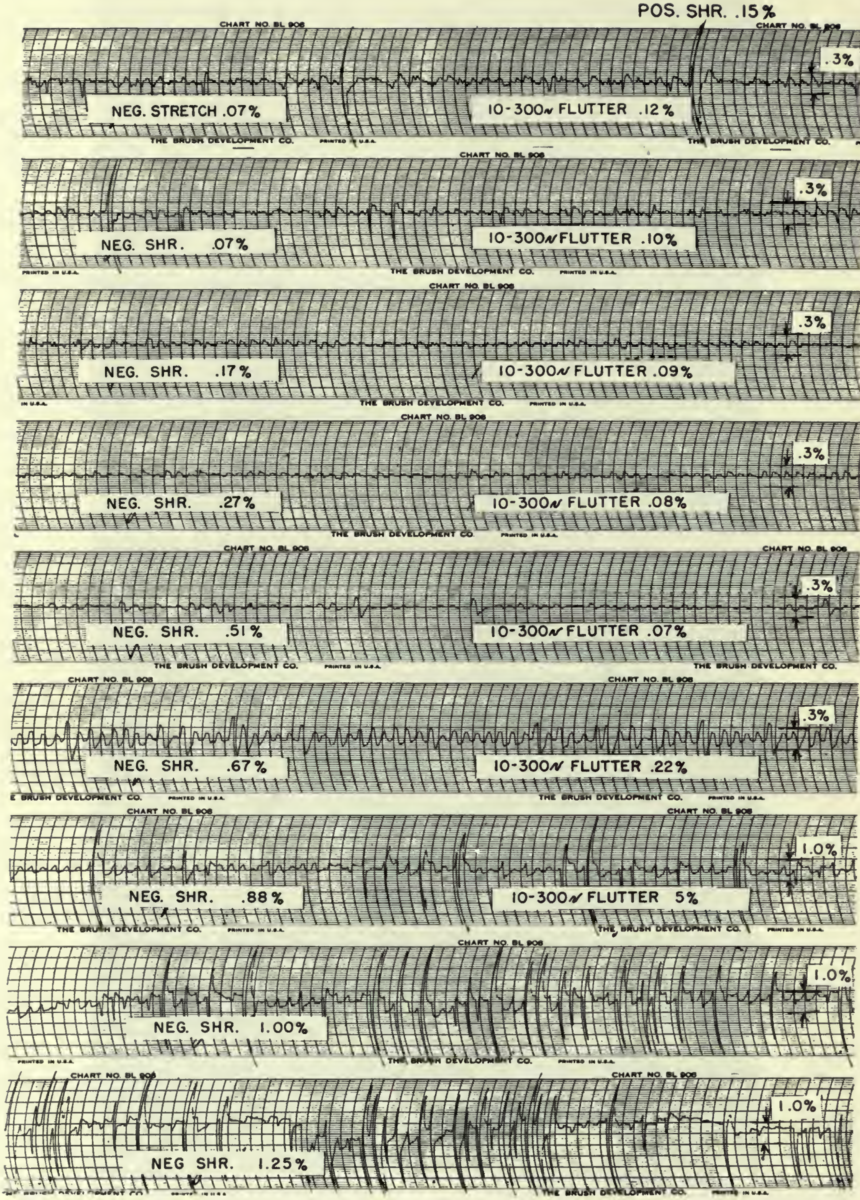


Fig. 15. Fluttergrams of contact prints made on conventional commercial 16-mm contact printer.

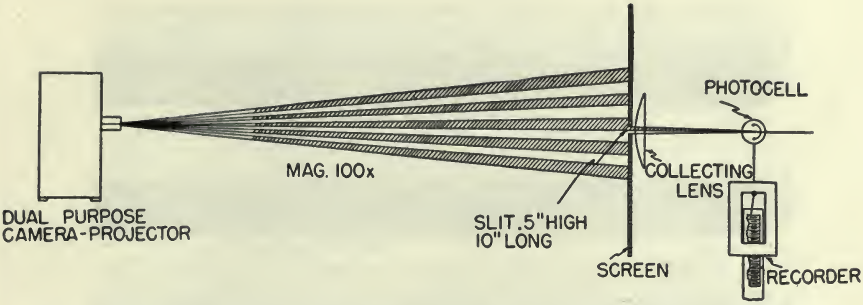


Fig. 16. Schematic drawing of setup used for recording picture steadiness.

As in the case of the sound tests, exposures were made on stock perforated to simulate shrinkages of from zero to 1%. The film was registered in the step printer by means of a registration pin whose position relative to the pull-down claw was adjustable, depending on film pitch.

The image exposed on the film consisted simply of a grid of clear and opaque horizontal bars. Such a pattern is well suited both to subjective steadiness observations and to physical measurement of image motion. Unsteadiness introduced by continuous contact printers usually exhibits itself as vertical motion of local areas of the image, rather than of the entire frame. This produces a rubbery image.

The setup used for making physical measurements of steadiness is shown in Fig. 16. The grid-type image on the film is projected onto the screen so as to eclipse part of a narrow horizontal slit in the screen. A collecting lens directs the light passing through the slit onto a photocell connected to a d-c amplifier and a Brush graphic recorder. Since the shutter in the projector interrupts the light once per frame, the recorder records a series of pulses, one for each frame, the amplitudes of which depend on the vertical position of the successive images on the slit. The whole system is adjusted so that a change in pulse amplitude of 1 cm represents an image motion of 0.001 in. at the projector gate.

Figure 17 shows steadiness charts, made as described above, on the series of negatives of various pitches. Since these test negatives were exposed and projected on the same mechanism, the registration was consistent, i.e., the same perforation was used to register a given frame during projection as during exposure. This type of check is, therefore, mainly one on the consistency of the exposing and projection mechanism. Since the charts show an unsteadiness of only about ± 0.0001 in. from the mean position, the reliability of the step-printer mechanism for exposing negatives and projecting prints is demonstrated.

If, now, the test negatives are projected in the reverse direction from that in which they were exposed, charts of the type shown in Fig. 18 are obtained. In this case, each frame is registered by a perforation five frames removed from the one used in exposure. This comparison demonstrates the importance of using consistent registration in all the operations to which a film is subjected, if the ultimate in image steadiness on the screen is to be achieved.

In continuous printers using variable-pitch sprockets, the perforation or perforations by which a given frame is registered, during the time it is being printed, depends on the shrinkage.

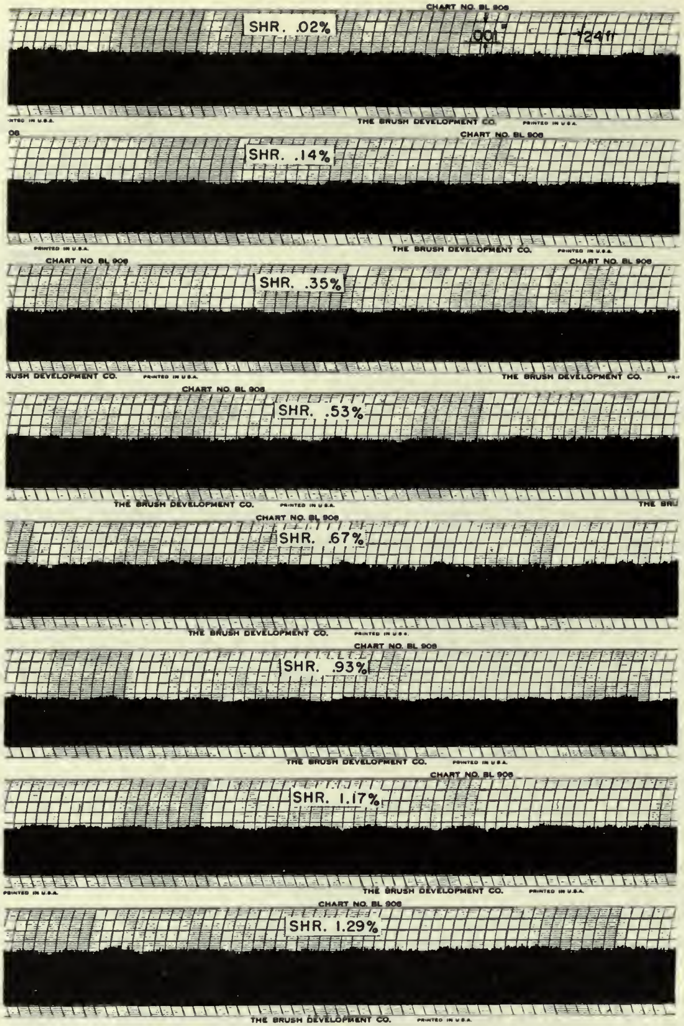


Fig. 17. Steadiness recordings of picture test negatives; consistent registration during exposure and projection.

This is true of both negative and print stock and, therefore, two inconsistencies in registration occur between camera exposure and print projection, each of which contributes to the unsteadiness of the projected image. The total unsteadiness is thus caused, in part, by these inconsistencies in registration and, in part, by poor longitudinal positioning of one or both films by the sprocket, as explained earlier. Good printer design can contribute to a reduction of only the latter source of unsteadiness.

In Fig. 19 is shown a series of steadiness graphs on prints made on the

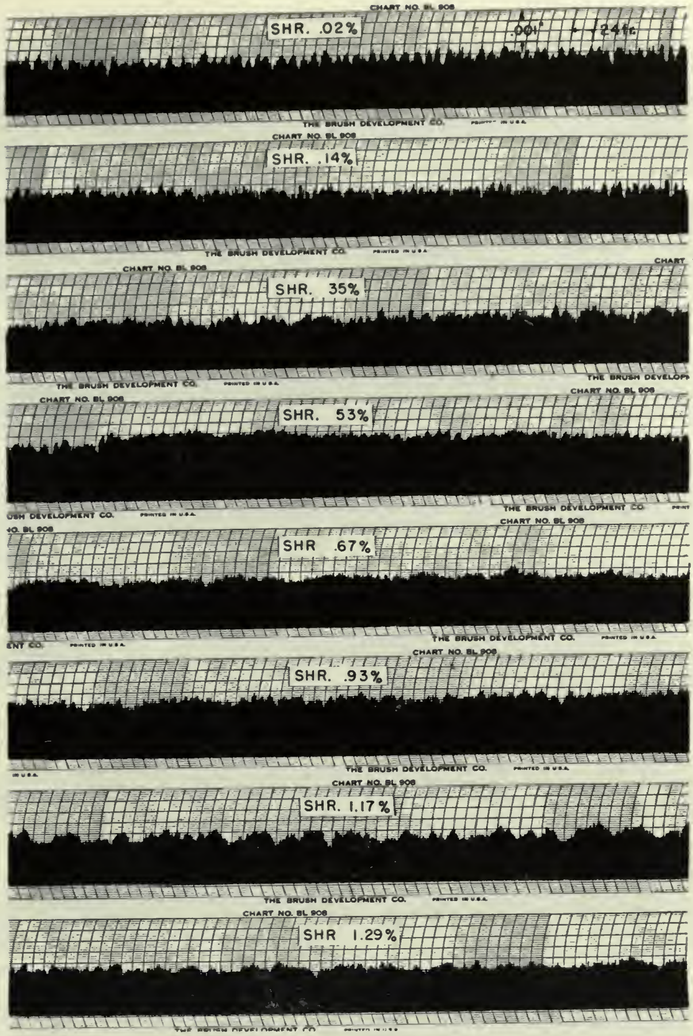


Fig. 18. Steadiness recordings of picture test negatives; registration during exposure and projection inconsistent.

radial-tooth sprocket from the test negatives. The graphs indicate that the sprocket is capable of making equally good prints, regardless of negative shrinkage, up to a shrinkage of 1.30%. If drift is discounted, the unsteadiness is seen rarely to exceed ± 0.00025 in.

For the purpose of comparison, a similar set of prints was made on a conventional commercial 16-mm contact printer. These are shown in the graphs of Fig. 20. Both the rate and the amplitude of unsteadiness are seen to depend markedly on the negative shrinkage.

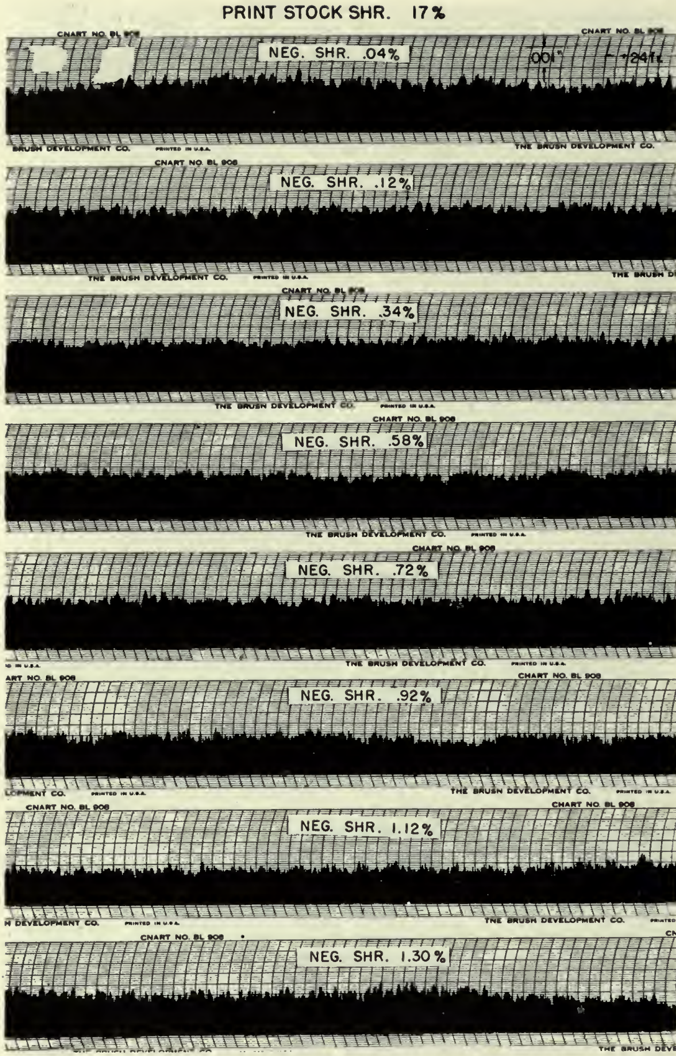


Fig. 19. Steadiness recordings of contact print made on radial-tooth, variable-pitch sprocket.

Other Applications

The variable-pitch, radial-tooth sprocket can undoubtedly be used to advantage in other applications. Optical printing would presumably benefit to about the same degree as contact printing. In this case, two precision sprockets, preferably on the same shaft, would be required, but each would be designed for optimum performance in the shrinkage range it had to accommodate.

In general, such sprockets designed for sound recorders or reproducers

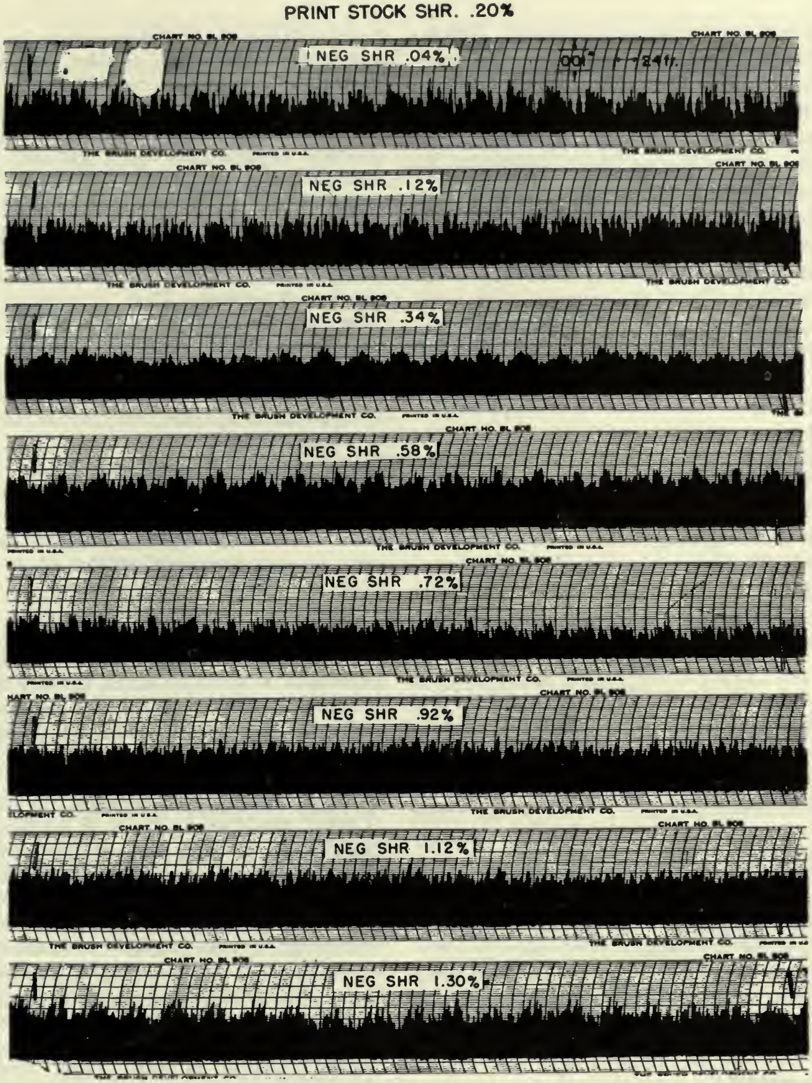


Fig. 20. Steadiness recordings of contact prints made on a conventional commercial 16-mm contact printer

would be larger in diameter than conventionally used drum drives. It is believed that filtered drives for such sprockets could be designed which would be substantially free of wow and which would be much more reliable and easier to maintain than drum drives.

High-speed continuous cameras and projectors would be improved markedly by such a sprocket, it is believed.

It might be thought that a shrinkage-accommodating printer, such as the one described, might be used to expose short-pitched duplicate negatives from

normal-pitched master positives. While it might be possible to design a sprocket which would accommodate the pitches involved, the procedure is not to be recommended because of the large amount of slippage which would occur between the films. If, however, a printer were equipped with an auxiliary lamphouse so that the films could be illuminated either from the outside or from the inside of the sprocket, then such duplicate negatives could be made by running the normal-pitch master positive on the outside and the short-pitch duplicate negative stock on the inside, and the slippage would be a minimum.

Conclusions

The radial-tooth, variable-pitch sprocket appears to offer a comparatively simple and inexpensive means for improving the performance in many forms of equipment which require uniform film motion.

Acknowledgment. The author gratefully acknowledges the many helpful suggestions of Dr. Otto Sandvik and Dr. J. S. Chandler made during the course of this work and the preparation of this paper.

References

1. L. A. Elmer, U. S. Patent 2,122,458, June 30, 1936.
2. E. Mechau, U. S. Patent 1,873,778, March 27, 1931.
3. J. S. Chandler, "Some theoretical considerations in the design of sprockets for continuous film movement," *Jour. SMPE*, vol. 37, pp. 164–176, Aug. 1941.

Discussion

Mr. F. Eich: Can radial-tooth sprockets of larger diameter than the 25-tooth sprocket described in your paper be designed?

J. G. Streiffert: Yes, somewhat larger. It depends on the shrinkage range to be accommodated and the velocity variation (flutter) which can be tolerated. For a given shrinkage range, the working height of the tooth is directly proportional to the sprocket radius. In order to have a practical tooth thickness, it would be necessary to reduce the angle of wrap so that there would be about the same number of pitch lengths in the arc of engagement, as in the case of the 25-tooth sprocket described. That is, instead of using the whole 180° arc, you perhaps would use only 90° total arc.

Anon: Have measurements of high-frequency loss been made on prints made on this type of sprocket from the negatives of various pitches?

Mr. Streiffert: No, we are doing that just now. We expect that the amplitude modulation in a constant-frequency print will be substantially less than in a print made on a conventional printer when the pitch differential is unfavorable.

Author's note added at publication time:

It should be emphasized that slippage between films having a large shrinkage differential is not eliminated by this type of sprocket, but is only made relatively uniform. This means that the printing aperture must be kept narrow enough (approximately 0.020 in.) so that the slippage which occurs between the films as they pass the aperture is negligible. The slippage between films of large shrinkage differential is usually quite nonuniform on conventional sprockets. The films stick together for a substantial part of each pitch length of travel and then slip relative to each other more or less instantly. Since the printing aperture is usually 0.100 in. to 0.300 in. in height, the definition is seriously degraded during a substantial fraction of each pitch length, while the remainder of each pitch length has good definition, because no slippage occurred while it was being printed. This results in a large amount of amplitude modulation in addition to frequency modulation (flutter).

Carbon Arcs for Motion Picture Studio Lighting

By W. W. LOZIER and F. T. BOWDITCH

A description is given of the technical characteristics of carbon-arc lamps which make them outstanding for motion picture studio lighting. These include penetrating power, covering power, shadow sharpness and spectral properties of the radiation. These are considered in relation to the requirements of various types and sensitivities of color film.

The unique and important properties of carbon-arc lamps which have made them so essential for studio lighting are well known among professional motion picture studio people.[1] However, the technical bases underlying some of these aspects and their quantitative magnitudes have not been so widely recognized. The recent introduction of faster color films and of films which have been balanced for a lower color temperature, makes an appraisal of motion picture studio lighting with carbon arcs appropriate at this time.

The merits of carbon-arc lamps are recognized among cinematographers and other personnel of the motion picture studios in such nontechnical terms as their superior ability "to penetrate deep sets," "to cut through general set illumination," "to produce modeling effects," "to simulate single-source-lighting," "to produce sharp shadows" and "to provide cool light." It will be shown that these features are attributable to tangible, technical characteristics which are measurable in numerical terms. Penetrating power, covering power, shadow sharpness and luminous efficiency are the related technical properties of lamps and radiation which will be discussed in this paper.

Figure 1 is a diagram of the optical system of a typical carbon-arc spot lamp.[2] A Fresnel lens is mounted so that it may be positioned over a range of distances from the positive carbon crater, with a maximum limit close to the focal length of the lens. This lens directs the light into a diverging beam with a spread dependent upon the lens position, and increasing as the lens is moved closer to the crater. The beam spread of present-day carbon-arc lamps ranges from 10–

Presented on October 19, 1951, at the Society's Convention at Hollywood, Calif., by W. W. Lozier, Carbon Products Service Dept., National Carbon Co., Division of Union Carbide and Carbon Corp., Fostoria, Ohio, and F. T. Bowditch, Research Laboratories, National Carbon Co., Division of Union Carbide and Carbon Corp., Cleveland, Ohio.

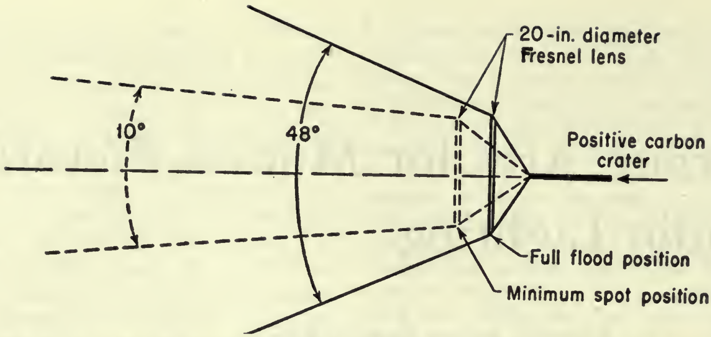


Fig. 1. Diagram of optical system of Type 170 carbon-arc spot lamp.

13° at minimum spot, with the lens near its focal position, to 44–48° at full flood, with the lens closest to the arc. As the lens is moved closer, it intercepts a larger cone of light to give a greater total illumination than at the position for minimum spot.

At any given beam spread, the light intensity in front of the lamp decreases with increasing distance approximately in accordance with the inverse square law. It is thus conventional to specify the light output for a given condition in terms of a beam candle-power value which can be divided by the square of the distance from the lamp to give the light intensity which will be produced at a position in the beam. Such data, supplied by the Mole-Richardson Company, are given in Table I for the three most popular carbon-arc spot lamps.[3] The greater concentration of the beam at minimum spot more than offsets the smaller light collection and results in much greater beam candlepower than at wider beam spreads. This higher candlepower is, of course, effective over a much smaller angle.

The color quality of the light from high-intensity carbon arcs is suitable directly or with only minor filtering for photography with color films balanced for daylight. With film balanced for lower color temperatures, a greater proportion of red than green, and of green than blue light is needed, so that a white-light source must have a great deal of its blue and green content removed when used with such a film. For instance, with a blackbody at 3350 K, the green content is about twice, and the red content three times, that of the blue. In order to match this radiation, a white-light source, or one with approximately equal energy at all wavelengths, requires a filter which will dissipate at least two-thirds of the blue and one-third of the green radiation present in the source — a theoretical loss averaging about one-third. The present state of the art with

Table I. Characteristics of Carbon-Arc Studio Lamps

Lamp	Light source, carbon	Fresnel lens diam., in.		Beam Spread: For 10% of center intensity	Beam Spread: For 50% of center intensity	Apparent candlepower at center of beam	Beam lumens*	Approx. apparent source size, in.†: Visual	Approx. apparent source size, in.†: Photometric
Type 450 "Brute"	225-amp, 16-mm	24	Min. spot	12°	5°	10,000,000	117,000	23.5	13.3
			Full flood	48°	35°	1,000,000	260,000	4.1	3.4
Type 170	150-amp, 16-mm	20	Min. spot	10°	4.4°	5,700,000	47,000	19.5	9.7
			Full flood	48°	42°	300,000	130,000	1.8	1.2
Type 90	120-amp, 13.6-mm	14	Min. spot	10°	5°	2,040,000	18,700	13.3	6.9
			Full flood	44°	43°	130,000	62,500	1.8	1.3

* Boundary intensity 10% of center intensity.
† Horizontal dimension as viewed visually and photometrically from the beam through the Fresnel lens.

respect to particular color films is defined in the following paragraphs.

1. 150 Foot-Candle Film Balanced for 3350 K. For the purposes of this discussion, it has been assumed that a deep amber filter of approximately 50% foot-candle transmission will adapt the carbon-arc illumination to this type of film.* This is characteristic of the gelatin filter combination presently being used with Technicolor film of this type, although a significantly greater transmission is at least theoretically possible, as indicated previously.

2. 300 Foot-Candle Film Balanced for Daylight. It has been assumed that, in accordance with present studio practice,[1] a light yellow Y-1 gelatin filter of 90% transmission will render carbon-arc lamps suitable for use with this type of film.

3. 450 Foot-Candle Film Balanced for Daylight. The filtering here is assumed to be the same as for the preceding case.

Penetrating Power

An outstanding feature of carbon-arc studio lamps is the very great beam candlepower of a single unit. This makes possible great *penetrating power*, or the ability to project useful intensities of light from great distances. One advantage of great penetrating power lies in the ability to produce a more even illumination along the useful length of the beam, across the set. If a comparatively weak lamp must be placed close to a set of appreciable depth, the light intensity from this lamp will vary markedly along its path across the set. This effect can be minimized only by using a more powerful lamp at a greater distance so that the depth of the set is a smaller fraction of the projection distances involved. Figure 2 indicates the penetrating power of the different carbon-arc lamps for equivalent photographic effect at the center of the beam, with each of the three types of film described above. It shows the distances at which the lamps, properly filtered, will project 150, 300 and 450 ft-c of illumination for each of the types of color film. With the beam spread adjusted for minimum spot, the indicated intensities can be projected approximately three times as far as when the lamps are adjusted for full flood. At minimum spot, the most powerful lamp can project the indicated intensity more than 180 ft for the 150 ft-c film and more than 170 ft for the 300 ft-c film.

Figure 3 shows the depth of set which can be illuminated within plus-or-minus 20% of the specified light intensity in each case. It is noted that the more powerful lamps and the small beam spreads are required to illuminate sets deeper than 25 ft with this degree of uniformity. Of course, a number of weaker units might be located at a similar distance to produce equivalent uniformity across the set, but this produces multiple shadows which are sometimes objectionable.

Covering Power

The photography of many scenes, particularly those involving outdoor lighting, requires that the effect of a single

---

* *Note.* Recent filter developments indicate the likelihood of being able to transform carbon-arc-lamp radiation to a quality suitable for 3350 K color films with substantially higher transmission than the 50% value assumed in this paper. This will correspondingly increase the light available from such filtered lamps and will increase the quantities representative of 150 ft-c, 3350 K film plotted in Figs. 2, 3, 4 and 6 by the square root of the ratio of the increase in light output. For example, increasing the filter transmission to 60% instead of 50% would increase the light output of the filtered lamps by 20%, and would increase the penetrating power, the range of projection distance, the covering power and the shadow sharpness for 150 ft-c, 3350 K film by about 10% over the values shown in Figs. 2, 3, 4 and 6.

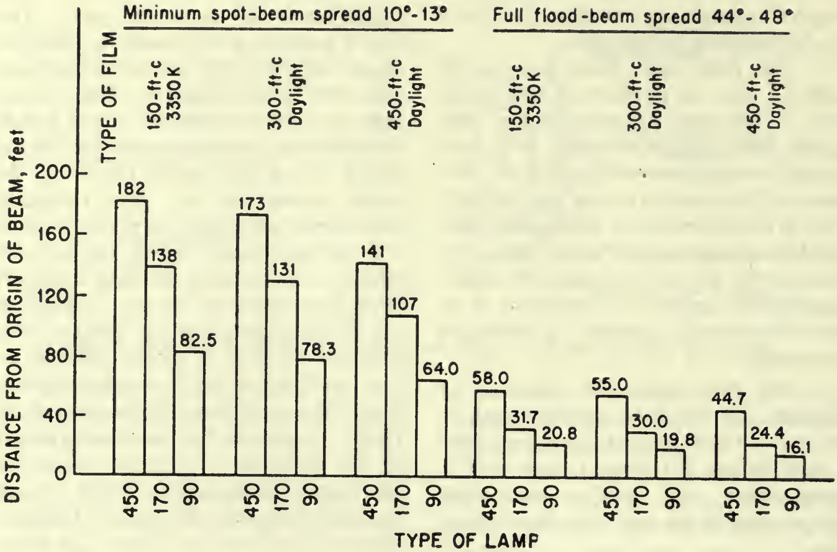


Fig. 2. Penetrating power (projection distance) of carbon-arc spot lamps for equivalent photographic effect at the center of the beam with three types of film. Allowance has been made for proper color filters.

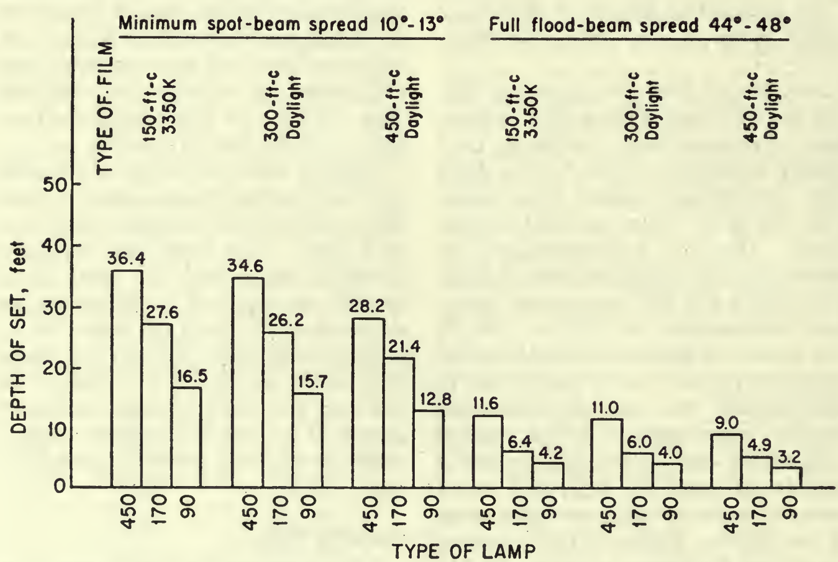


Fig. 3. Range of projection distance of carbon-arc spot lamps for ±20% variation in intensity. Same conditions as Fig. 2.

source be produced over a considerable area. In these cases, the area which can be covered with a single lamp is of interest. The ability of a carbon-arc lamp to cover a large area is attributable to the high lumen content of the beam. The area of a set which can be illuminated to a given intensity with a single lamp is definable in terms of the diameter of the spot over which this intensity can be secured. This diameter is called the *covering power* of the lamp for the purposes of this paper, and depends upon the projection distance and the beam spread. The boundary of a projected light beam is conventionally taken as the point where the light intensity is 10% of that at the center. Since more than 10% of maximum intensity may be required for photographic purposes, values of the covering power for boundary intensities 50% of the center value are also given. Figure 4 shows the covering power so defined for the carbon-arc lamps and the film conditions considered in the preceding charts. The total height of each block indicates the covering power with a 10% boundary intensity; the horizontal line across each block at a lower value indicates the covering power of the same source, but with the 50% boundary intensity. The lamps at minimum spot can cover set widths from 10 ft to 40 ft on the basis of a 10% boundary intensity. For a 50% boundary intensity, the minimum spot coverage is approximately half as great.

The covering power at full flood is substantially greater than at minimum spot, on account of the greater lumen output at the flood position. Also, the covering powers for the 50% and 10% boundary intensities are more nearly identical at full flood, as a result of the more uniform distribution across the wider beams.

It will be noted that the areas which can be illuminated to a given intensity will depend on the square of the corresponding beam diameters shown in Fig. 4. These areas cannot be simply specified in a general way, since the beam ordinarily strikes the set at an angle determined in each case by the effect wanted.

Sharpness of Shadow

Figure 5 illustrates the formation of a shadow by a light source. The sharpness of the shadow is determined by the source size and its distance from the object, these in turn fixing the angle subtended by the source at the shadowed object; the smaller this angle, the sharper the shadow. It is a characteristic of the Fresnel lens optical system at full flood that only a small portion of the lens area is effective in directing light to a particular object in the beam. As the lens is adjusted toward the minimum spot position, this effective area increases. Therefore, shadows of objects placed at the same distance from a given lamp will be sharper when the lamp is adjusted for full flood than for minimum spot.

The effective horizontal dimensions of the sources for the extremes of beam spread were measured for each lamp with the results shown in Table I. These were determined both visually and by recording with a photocell the intensity variation across the shadow formed by an opaque straight edge. The latter determinations were based upon the width of shadow between the points at which the light intensity was 10% and 90% of the unshadowed intensity. The source sizes so determined were found to be smaller than those visually observed, as shown in Table I, and are believed to be a better measure of photographic shadow sharpness. The edges of the luminous spot on the lens surface are not sharply defined, the light tapering downward over a bandwidth which is difficult to define with the eye alone. Thus, although the entire area of the Fresnel lens appears visually luminous when set for minimum spot, much of the outer area is of relatively low brightness and is essentially ineffective in contributing to the shadow formation.

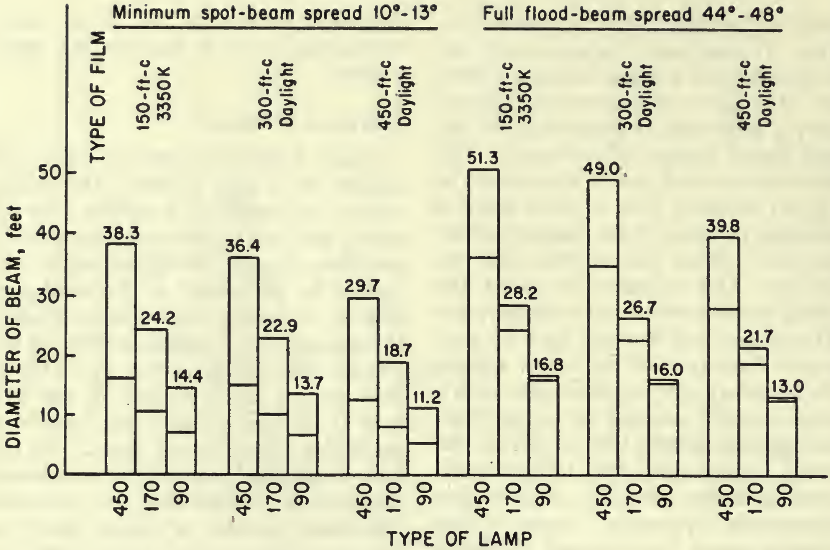


Fig. 4. Covering power (diameter of beam) for carbon-arc spot lamps for same conditions as Fig. 2. Upper and lower values correspond respectively to intensities at the beam boundary of 10% and 50% of center intensity.

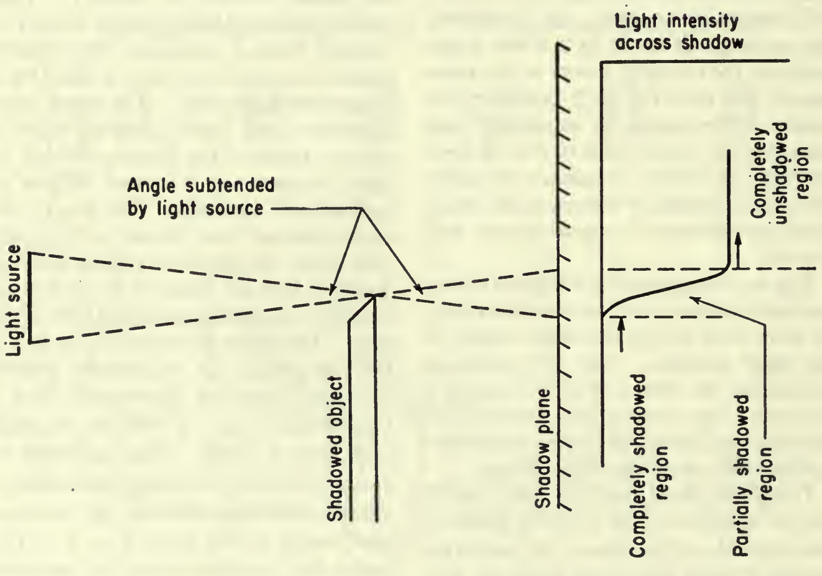


Fig. 5. Diagram showing how sharpness of shadows depends on angle subtended by the light source at the shadowed object.

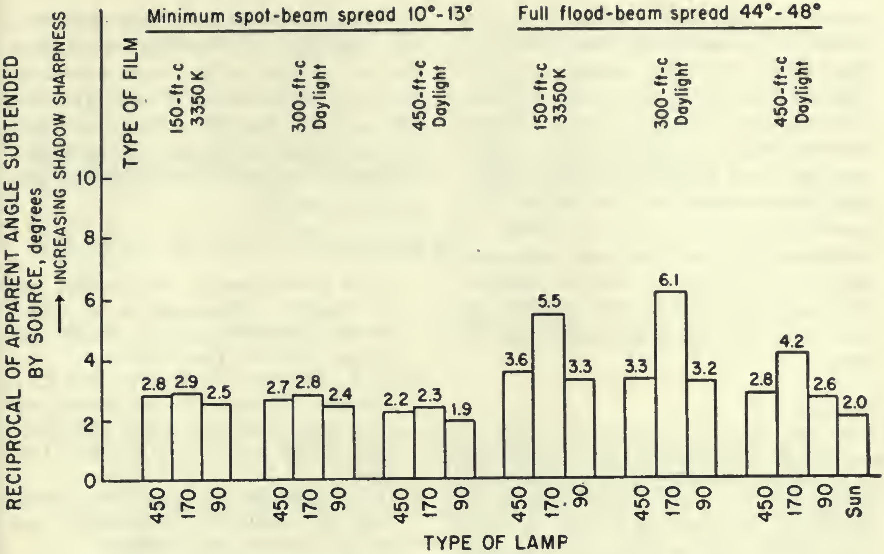


Fig. 6. Shadow sharpness from carbon-arc spot lamps for same conditions as Fig. 2.

In order to secure a measure of shadow sharpness which increases with increasing sharpness, the reciprocal of the subtended angle, measured in degrees, has been chosen. This reciprocal value is shown in Fig. 6 for the lamps and films under consideration. For comparison, the value of 2.0 which measures the sharpness of shadows produced by the sun is included. Values higher than 2.0 indicate shadows sharper than those of the sun, while lower values give more fuzzy shadows.

It will be noted that all the carbon-arc lamps at all conditions shown in Fig. 6 produce a shadow sharpness essentially equivalent to or sharper than the sun. As previously indicated, markedly sharper shadows are produced at full flood than at minimum spot. It is the small source size and the high brightness of the carbon arcs which allow them to produce useful intensities of radiation with a shadow sharpness surpassing that obtained from the sun and from other studio-lighting sources.

Heat Per Unit Light

Thermopile measurements of the total radiant energy from the carbon arcs show that the unfiltered lamps have a luminous efficiency of approximately 75 to 100 lm per radiated watt in the light beam. This value is, of course, substantially higher than the lumens per watt of total arc power, since all the input power is not converted to radiation, and all the radiation is not focused into the light beam. Similar measurements using a gelatin filter combination with one "MT-1" and two "Y-1" filters resulted in approximately 50% loss in visual candlepower, but correspondingly reduced the total radiant energy, so that there was only a 10% to 20% loss in luminous efficiency. This filter combination is the one presently used with carbon arcs and 3350 K film. Incandescent tungsten lamps used for studio lighting are reported to have a luminous efficiency of 35 to 40 lm per radiated watt.[4] With or without the gelatin filter combi-

nation on the arcs, the luminous efficiency of the carbon-arc lamps is thus at least twice that with tungsten, to give half the heat for the same light intensity. This explains the much greater coolness conventionally associated with carbon-arc light, and indicates that this advantage is maintained with the gelatin filter combination and the new color films. It is interesting to note that the carbon-arc lamp approaches the sun in luminous efficiency as well as in color quality, the solar efficiency being approximately 100 lm/w.[5]

Summary

The small source size, high brightness and high unit power of the carbon arcs make possible their outstanding superiority in penetrating power, covering power and shadow sharpness compared to other available light sources. The daylight quality of the light is responsible for the coolness of the radiation and permits ready interchangeability with daylight in color photography.

It is expected that whether the carbon-arc lamps are used with their characteristic daylight color quality or whether they are filtered to the lower color-temperature requirements of new-type motion picture color films, their distinctive characteristics will continue to give them widespread application for motion picture photography.

References

1. R. G. Linderman, C. W. Handley and A. Rodgers, "Illumination in motion picture production," *Jour. SMPE*, vol. 40, pp. 333–367, June 1943.
2. F. T. Bowditch, M. R. Null and R. J. Zavesky, "Carbon arcs for motion picture and television studio lighting," *Jour. SMPE*, vol. 46, pp. 441–453, June 1946.
3. C. W. Handley, "Report of the Studio Lighting Committee," *Jour. SMPE*, vol. 47, pp. 113–118, Aug. 1946.
4. *IES Lighting Handbook*, Illuminating Engineering Society, New York (1947), Tables 6-2 and 6-3.
5. Parry Moon, "Proposed Standard Solar-Radiation Curves for Engineering Use," *J. Franklin Inst.*, vol. 230, pp. 583–617, Nov. 1940.

Magnetic Sound on 16-Mm Edge-Coated Film

By E. E. MASTERSON, F. L. PUTZRATH and H. E. ROYS

A small head for magnetic recording and reproduction has been developed to fit within the area of the sound drum of a standard RCA-400, 16-mm projector. The head mounting is such that the projector can be used for the two magnetic functions as well as photographic reproduction. The amplifier modifications included increasing the amplifier gain, using various compensating circuits, decreasing the oscillator distortion and means for eliminating the possibility of leaving the record-playback head in a magnetized state. Two switches, mechanically coupled, have been provided to permit the selection of the desired amplifier function.

Within the past few years magnetic recording has developed to such an extent that it is now recognized as one of the best sound recording means available. It is used extensively in broadcast stations, in disk studios for original recording, and in film recording studios where the sound is recorded magnetically and then transferred by the usual photographic means to prints for theater use. In the first two applications, thin tape, one-quarter of an inch wide, is generally used, but where picture and sound are combined and synchronism becomes necessary, film with sprocket holes is the common medium. Usually 35-mm film is used, it being either coated across the entire surface or only over the picture and sound track areas leaving the sprocket holes uncoated.

With such widespread acceptance it is only logical, therefore, that magnetic recording would be considered for 16-mm usage. An improvement in signal-to-noise ratio is available and a wider frequency response range is believed to be more easily obtainable. Furthermore, a magnetic track allows complete freedom in the choice of photographic emulsion and processing, and in addition, the recording may be put on or changed at any time since there is no processing involved for the magnetic track.

Magnetic sound with picture was demonstrated in 1947 by Camras* using

Presented on May 4, 1951, at the Society's Convention at New York, by E. E. Masterson, Eckert-Mauchly Computer Corp., Philadelphia, Pa. (formerly with RCA Victor Div.), F. L. Putzrath and H. E. Roys, Radio Corporation of America, RCA Victor Div., Camden, N.J.

* M. Camras, "Recent development in magnetic recording for motion picture film," *J. Acoust. Soc. Am.*, vol. 19, pp. 322–325, Mar. 1947, demonstrated at the Acoustical Society Meeting in Chicago, Nov. 15, 1946.

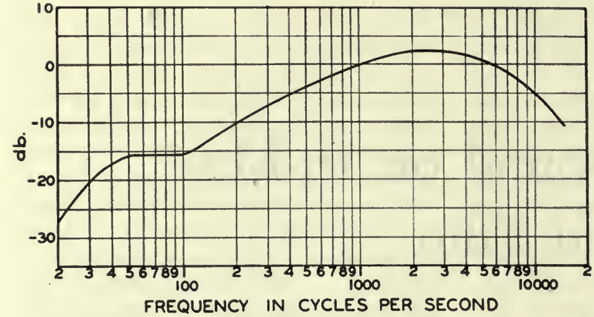


Fig. 1. Frequency-response characteristic of the small head at a tape speed of 15 inches a second, with constant recording current. The response characteristic of the playback was flat.

a film that he had edge coated. Schmidt demonstrated some edge-coated 16-mm film, that is now commercially available,† at the SMPTE Convention in the Fall of 1950. The machine used by Schmidt was an RCA engineering model and it is the purpose of this paper to describe that development model.

General Design Considerations

Existing 16-mm projectors are designed for reproduction of photographic recording, and in most cases, the sound track is scanned at the drum where the film motion is steady and the flutter a minimum. It is the usual practice in magnetic recorders, however, to locate the recording and reproducing heads ahead of the driving capstan, and to depend upon the capstan and a stabilizing flywheel to impart smooth motion to the medium. The capstan in this case corresponds to the sound drum in the sense that the function of both is to impart uniform, flutter-free motion to the medium, although in most projector designs the sound drum is driven by, instead of driving, the film.

Examination of the RCA-400 projector reveals that there is little room to mount a magnetic head either before or after the sound drum without altering the film path and introducing additional idlers and flutter-eliminating devices.

Normally the base side of the film is in contact with the surface of the sound drum so that the magnetic track, being on the base side, would extend beyond the inside edge of the drum. If the head is to contact the film within the drum area it is therefore necessary to locate the head between the shaft and the periphery of the drum. This does not provide much mounting space and it therefore is not attractive mechanically; however, there are certain advantages that must be considered. The flutter should have a minimum value since the film is in contact with the sound drum; in addition, the distance between picture and sound can be maintained the same as for photographic recordings. Although at the time the development was being considered no standards or proposals for the location of magnetic tracks existed, it was believed that an agreement on any different separation between picture and sound would be impossible, since so many projectors of various designs were in existence. Therefore, it appeared wise to try a small head within the area of the sound drum.

Magnetic Head Development

The projector drum and the shaft are 0.880 and 0.3143 in. in diameter, respectively, which leaves a radial depth of 0.283 in. for the magnetic head, so it became necessary to limit the maximum height of the head to 0.250 in.

† Edward Schmidt, "Modernized commercial sound recording," paper presented on Oct. 19, 1950, at the Society's Convention at Lake Placid, N.Y., with demonstration of film available from Reeves Soundcraft Corp., Long Island City, N.Y.

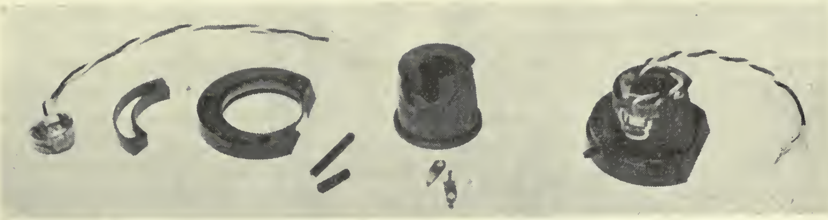


Fig. 2. Head and mounting assembly.

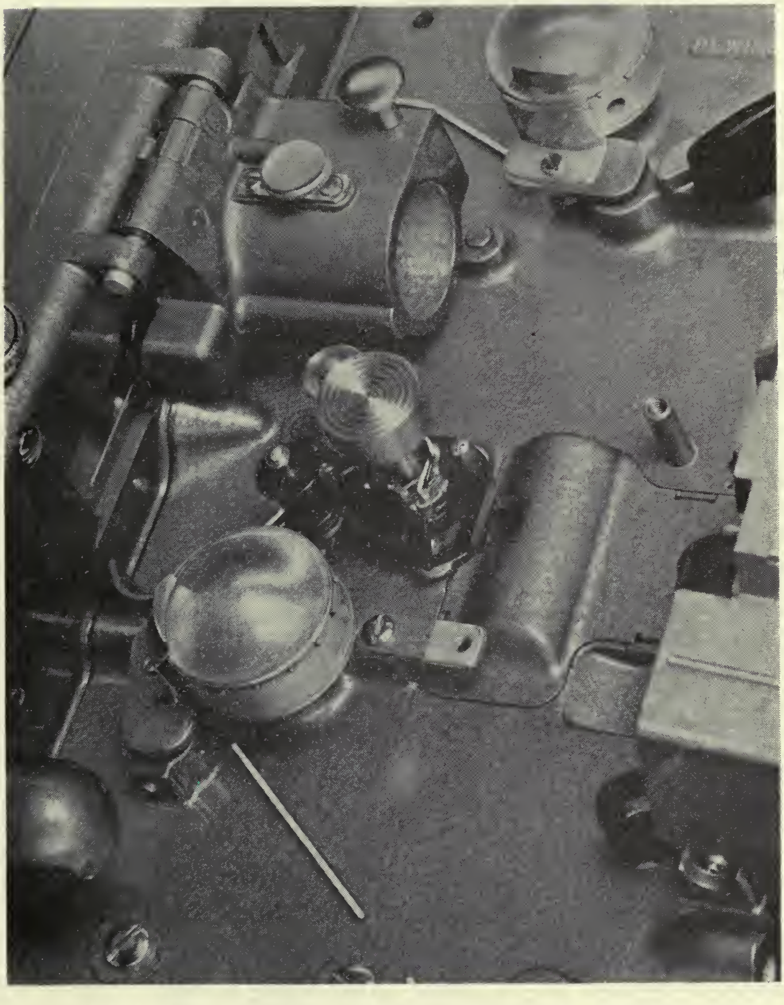


Fig. 3. Head and mounting assembled in place on the Model 400 projector. The sound drum was withdrawn slightly in order to obtain a better view.

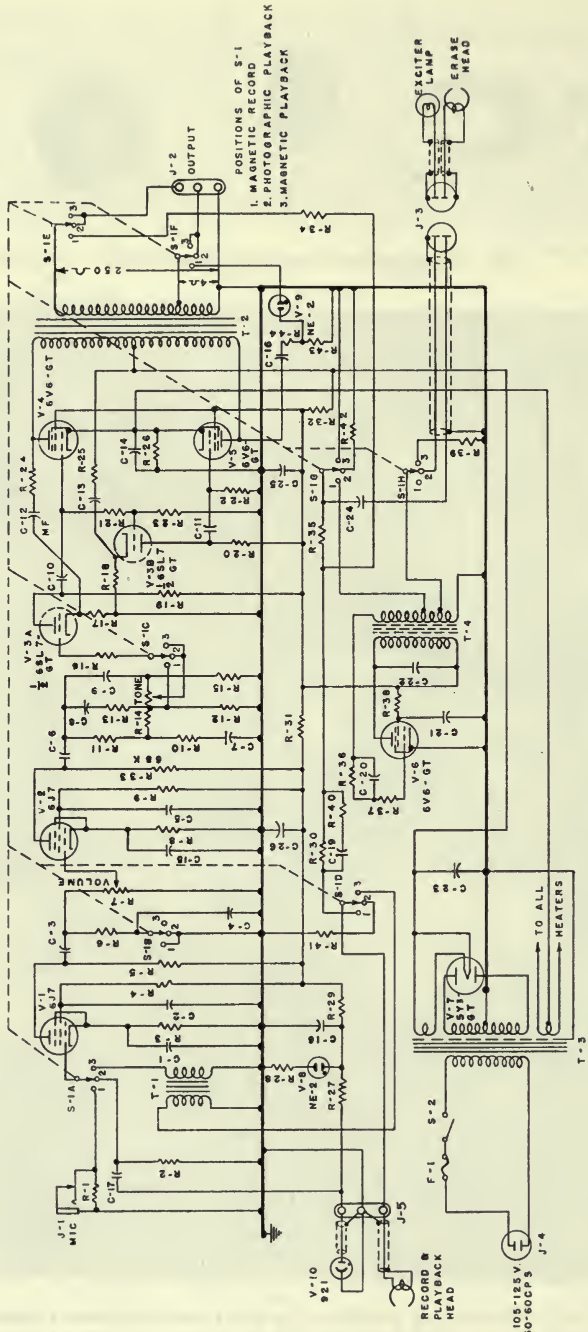


Fig. 4. Circuit of the modified amplifier.

An experimental head was constructed to fit within the allotted space and an engineering demonstration was given during the latter part of 1948. The results were encouraging and further consideration was given to a new design which would incorporate features found desirable during the earlier work.

A small head was designed and extensive tests were made using $\frac{1}{4}$-in. tape operating at 15 in./sec, in order to obtain a comparison with broadcast-type heads. On an equivalent impedance basis the small head showed a 3-db increase in output over a larger ring-type head of conventional design. A frequency-response characteristic with constant current input is shown in Fig. 1. The flat portion or shelf between 100 and 50 cycles is due to the relative physical dimensions of the magnetic structure with respect to the length of the recorded waves. There appears to be no objection to this shelf, in fact there is the advantage of an increase in output at these lower frequencies where hum is usually present. At a medium speed of 7.2 in./sec, which corresponds to the normal 16-mm sound speed of 24 frame/sec, this shelf would be moved downward by an amount proportional to the speed change (15 to 7.2 in./sec).

The head is mounted in a cylindrical housing through which the drum shaft protrudes. Both the magnetic head and the mirror, used for photographic reproduction, are mounted in cutout portions of the cylinder. The cylinder is clamped by means of a ring, and is rotatable to permit positioning of the mirror or the head for either photographic or magnetic operation. Two stops, one adjustable, are provided to limit the rotation of the cylinder. The cylinder is mounted eccentrically with respect to the sound drum to provide a means of adjusting the contact pressure between the magnetic head and the magnetic track. Azimuth alignment is accomplished by rotation of the head within its housing. The magnetic head does not contact the film during photographic reproduction and therefore cannot scratch or mar the sound track and cause noise during playback. The head and mounting parts are shown in Fig. 2, in various stages of assembly. Figure 3 shows the arrangement mounted on an RCA-400 projector.

Amplifier

The amplifier modified for this development was the same as used in the standard RCA-400 projector. Normally a phototube is used as the input source although for sound reinforcement purposes the input of the amplifier can be switched to operate from a high-impedance microphone. The amplifier has one pentode and two triode amplifier stages, with a triode phase inverter and two push-pull output tubes that deliver 10 w of audio power into the speaker. Two readily accessible controls are used, one for volume and the other for tone, the latter tilting the frequency response about an 800-cycle center frequency.

In the new amplifier all of the normal photographic reproduction requirements are met, and additional facilities for magnetic recording and reproducing of sound on edge-coated film are provided. A means of erasing has been included so that changes can be made, or the entire film erased for re-recording. Erasing can be accomplished only with the switch in the magnetic recording position.

The signal for the grid of the first voltage-amplifier stage, a 6J7, can be obtained from three different sources (see Fig. 4): a high-impedance microphone for magnetic recording, the phototube for optical playback, and the record-playback head through an input transformer for magnetic playback. The step-up ratio of the input transformer is limited by the resonance of the head inductance with the transformer secondary winding capacitance. The frequency of this resonance is adjusted to fall slightly beyond the useful audio range of the playback system as deter-

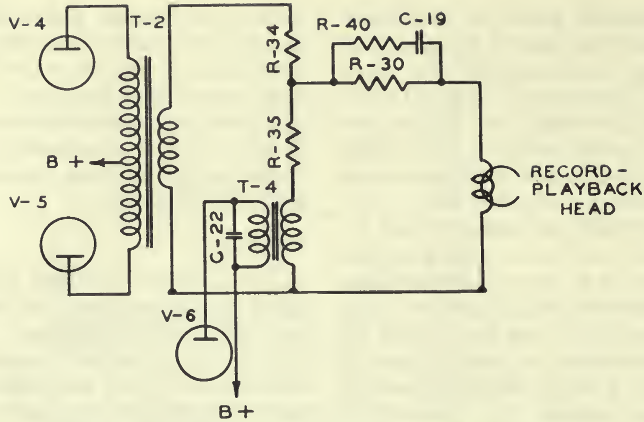


Fig. 5. Recording circuit for the magnetic head.

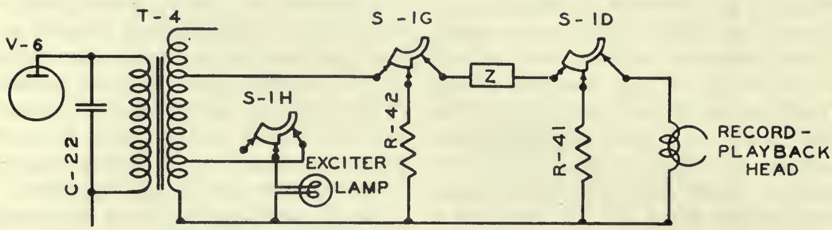


Fig. 6. Circuit for reducing the bias current at the record-playback head.

mined by the head gap and the film speed. Although the Q of this resonant circuit is very limited due to the losses in the magnetic head, a 2-db rise at 7.5 kc has been realized.

The plate circuit of the first stage has the necessary low-frequency compensation when the amplifier is used for magnetic playback. During the other two functions this compensation is left out. The volume control is placed here to avoid overloading the low-level amplifier stage when considerable attenuation is used. The subsequent voltage-amplifier stage is a 6J7 followed by the tilt-type tone control. During magnetic recording the tone control action is removed by connecting the following 6SL7-GT grid to the center point of the control resistor.

Two 6V6-GT's in push-pull are used as power amplifiers obtaining their signals from the 6SL7-GT voltage amplifier and phase inverter with overall negative feedback. The feedback loop characteristics are designed to be inherently stable with any type of amplifier loading. The 4-ohm and 250-ohm load windings of the output transformer are used and both are connected to the load jack during either playback function. However, during the magnetic recording the 4-ohm winding is used to complete the connection of the recording level indicator, an NE-2 glow lamp. In the magnetic recording switch position the 250-ohm winding works into a tapped dummy load from which the proper amount of recording current is derived.

The oscillator supplies power to the exciter lamp during photographic playback while during magnetic recording it

supplies current to the recording and erase heads. Because these functions require several watts of high-frequency power, a tuned plate oscillator circuit using a 6V6-GT was selected. Care has been exercised in the oscillator circuit to limit harmonic distortion to amounts which do not adversely affect magnetic recording performance. An oscillating frequency of 50 kc was chosen to be sufficiently above the highest usable audio frequency and yet to keep the losses in the two heads to a minimum. The method of adding the high-frequency recording bias to the audio recording signal is shown in Fig. 5. The resultant signal then goes through the audio pre-emphasis network to the record-playback head. During magnetic playback the oscillator works into a dummy load.

The power supply system does not require special mention except that the phototube polarizing voltage is directly derived from the high-voltage supply and is essentially regulated by another NE-2 glow lamp. This regulation greatly reduces overall gain variations with line voltage fluctuations.

Several problems arise in the design, layout and location of the amplifier and its associated components along the film path. Using the same amplifier for three different purposes requires a careful arrangement of the amplifier components. A single control performs all

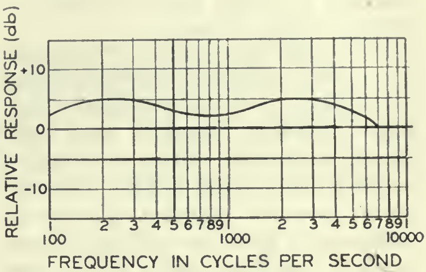


Fig. 7. Overall frequency response of the magnetic system.

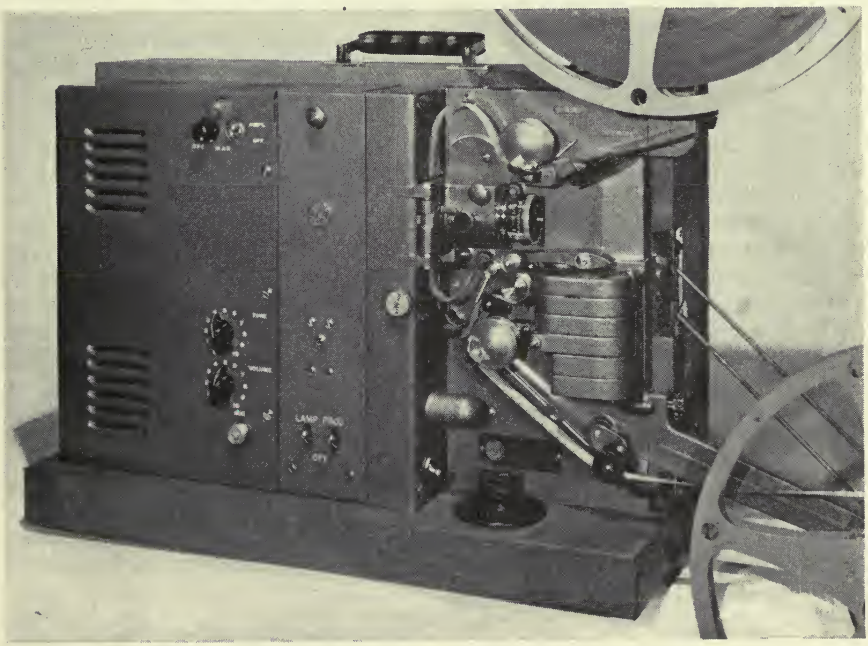


Fig. 8. The development model of the magnetic recorder.

necessary switching. Since only one head is used for magnetic recording and reproducing, circuit connections of the amplifier output to the input are involved. To provide some input-output isolation the magnetic recording and playback switch positions are separated and the necessary intermediate switching contacts essentially grounded. The resulting switching sequence permits the use of a mechanical interlock for the magnetic recording position which is a desirable safety feature.

To prevent large residual magnetization of the record-playback head when the amplifier is switched from the magnetic recording position, the high-frequency recording bias on the head is reduced step by step before it is completely removed. Shorting-type switches momentarily place two additional loads across the oscillator and a shunt across the magnetic head. In particular (see Fig. 6), the switch section S-1H connects the exciter lamp, and switch section S-1G adds a dummy load (R-42) to the oscillator; switch section S-1D adds the resistive shunt (R-41) across the head. As any two of these three switching operations will most likely not occur within the time passage of less than one-half cycle of the bias frequency, the bias will probably be reduced in three steps before either switch section S-1G or S-1D interrupts the flow of bias current completely.

Two more problems required attention for satisfactory amplifier performance. A certain amount of oscillator signal is coupled through stray capacities to the low-level amplifier circuits, and during magnetic recording, conductively coupled into the amplifier output circuit. Good wiring practice and circuit arrangement keeps these undesirable signals to levels below which the performance of the amplifier is adversely affected. The other problem encountered was hum pickup in the record-playback head from stray magnetic fields of the power transformer and the projector motor. Shielding and reorientation of these components adequately solves this difficulty.

Performance

The overall performance of the final amplifier can be briefly summarized as follows: The amplifier power output is 10 w with less than 3% total harmonic distortion from 100 to 3000 cycle/sec. For photographic sound track operation the amplifier performance remains essentially unchanged. During magnetic recording the film track can be fully modulated with 35 db of attenuation in the volume control without excessive distortion in the first voltage amplifier stage. The amplifier output networks are so adjusted that the 3% harmonic distortion point on the film is reached approximately 3 db before the amplifier begins to overload, thus giving an optimum signal-to-noise ratio during recording. The recording level indicator is adjusted to begin glowing 3 db before film overload is reached. Assuming fully modulated film, the amplifier has about 11-db gain reserve during playback and a noise level 50 db below rated power output with the projector in operation. The overall magnetic record-playback frequency response is flat within 5 db from 80 to 7500 cycle/sec (Fig. 7).

Proposals on the design and construction of the magnetic head by V. M. Grantham, and the development work on the feedback circuit by L. H. Good, are hereby acknowledged.

Cine-Interval Recording Camera

By ARTHUR P. NEYHART

A new type of electric cine-interval industrial and research recording camera, designed to produce a compact and reliable remotely controlled unit, is described. Requirements of one of the more difficult types of photographic recording, that of test aircraft instruments, are discussed. The application and results of electromagnetic clutch, as used to operate the Automax Recording Camera as both a motion picture and a still camera, are described.

The combination cine-interval camera used in aircraft flight-testing and other research activities can be generally described as a 35-mm camera which operates selectively as a motion picture camera and a still sequence camera.

Electrically operated and remotely controlled, this type of camera has a fixed motion picture frame rate in the 8- to 24-frame/sec range and a maximum single-frame rate of from 2 to 10 frame/sec. Continuous voltage supplied to the camera results in cine operation. Electrical pulses, usually supplied by an intervalometer or a switching device controlled by the action being recorded, produce interval operation.

The dual camera function permits the frame rate to be adjusted over a wide range to conform with the data recording frequency requirements of a particular test.

To illustrate, a test aircraft instrument recording camera may be operated as slowly as one frame per second during the climb to an altitude selected for a test. Instrument readings such as those denoting fuel consumption, engine cooling, rate of climb, developed horsepower and other pertinent data can be recorded adequately at this low frame rate. Upon reaching the required altitude, and after stabilizing for the test run, the camera is switched to a motion picture rate for the duration of the test. Because of rapid instrument reading changes which occur during most test runs, a relatively high recording rate is necessary to produce accurate data. At the conclusion of the run, the camera frame rate is reduced to record incidental descent data during the return to the field.

By not recording at higher frame rates than necessary, a considerable saving is effected in film reading, processing and in the space and weight of large film loads.

Up to the close of World War II, recording cameras of this type were largely designed and constructed by their users. This was particularly true in the aircraft industry, where about every known type of electric prime mover

Presented on October 16, 1951, at the Society's Convention at Hollywood, Calif., by Arthur P. Neyhart, Guild Laboratories, 6264 Sunset Blvd., Hollywood 28, Calif.

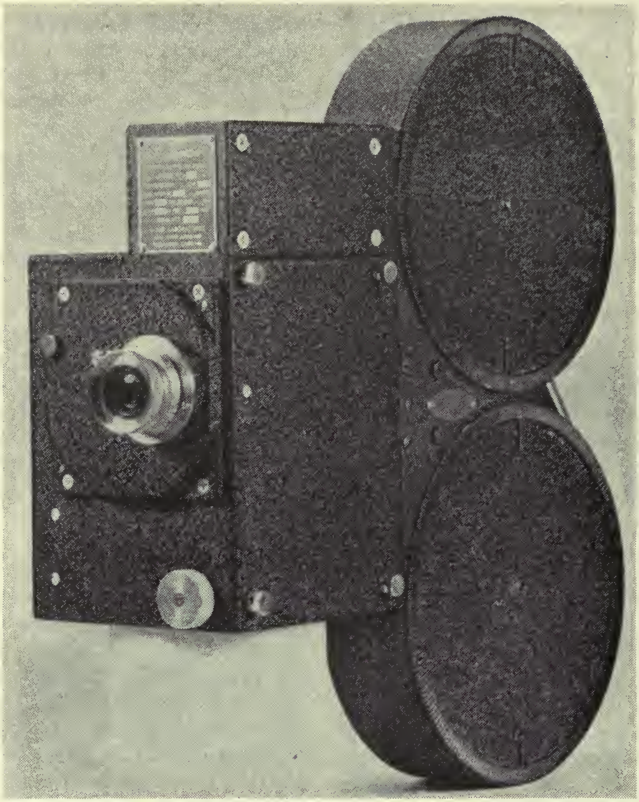


Fig. 1. Film-loading side of camera.

was applied to amateur and semi-professional cameras. As an example, one aircraft concern modified a DeVry Model A, 35-mm camera by adding a linear solenoid and ratchet combination to produce interval operation; cine operation was accomplished by a motor and free-wheeling drive. While this camera did a fair job, it was limited by a maximum interval frame rate of two per second, a wide variation in exposure between interval and cine operation, and frequent failures under accelerated conditions.

Design Problems

In the design of a cine-interval camera which will produce uniform exposures during both modes of operation, certain inertia problems are encountered. A camera, which operates basically at 16 frame/sec, or 960 cycle/min, will progressively expose the film for an effective period of 15.6 msec (milliseconds) with a 90° shutter. When this shutter is of 4-in. diameter, 23 msec will elapse from the time the first corner of the frame is uncovered until the last corner is capped. To produce an interval exposure equivalent to cine exposure, therefore, a camera must operate at the rate of 960 cycle/min during the 23 msec of each cycle required for the total exposure function.

An interval frame rate of 10 frame/sec, or one frame in 100 msec, requires the

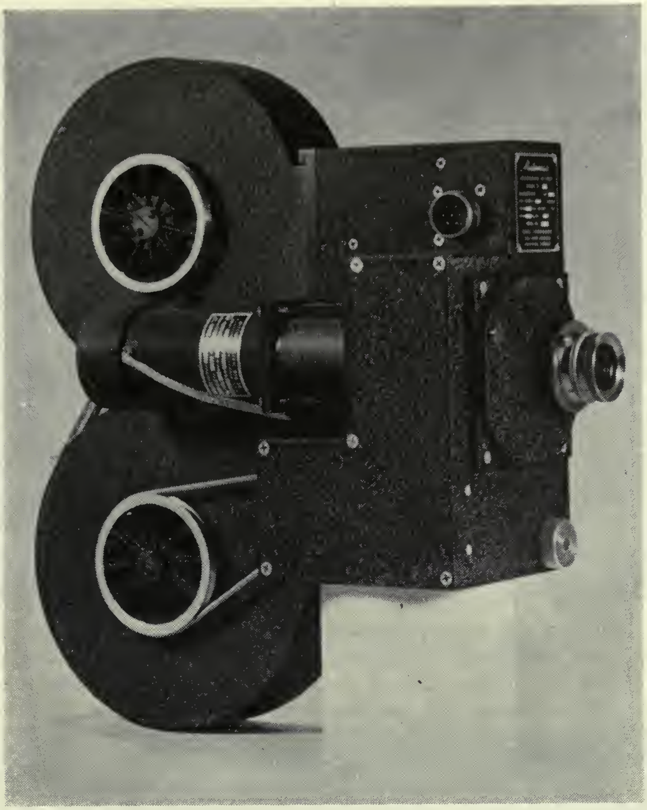


Fig. 2. Motor-driven side of camera.

camera to accelerate from a standstill to its cine speed in 38 msec, maintain that speed for a 23-msec exposure period, and decelerate to a stop in the remaining 38 msec of the cycle.

Aircraft Requirements

Airborne camera design requires consideration of the special conditions under which a camera must operate. Prolonged acceleration loads up to 10 *G*'s may be applied to any axis, ambient temperatures may range from −65 F to +160 F at relative humidities to saturation. Vibration frequencies up to 100 cycle/sec at amplitudes as high as 0.02 in. are often encountered and sound levels exceeding 100 db are not uncommon. Power source voltage frequently varies from 18 to 30 v during a flight. These and many lesser conditions, independently or in combination, materially increase the performance requirements of a recording camera.

The importance of dependable operation cannot be overemphasized, whether considering cameras for aircraft applications or for recording other types of costly or dangerous research. Tests repeated because of camera failure often cost many times the price of the equipment which failed. Aircraft testing cost averages from $1500 to over $5000 per flying hour; flights often exceed 5 hr in duration. Repeating flights because of loss of data through camera failure

not only represents a money and time loss but incurs an additional risk of crew and airplane.

Automax Recording Camera

Designed primarily for aircraft instrument recording, the 35-mm Automax camera (Figs. 1 and 2) is proving of value in other types of research recording requiring rates of 16 frame/sec and less.

A constant-speed-drive motor (Fig. 3), which may either be governer-controlled or synchronous, transmits power to the camera through an electromagnetic clutch and brake combination. The driven clutch disk, mechanically connected to the camera mechanism through a speed reducer, is positioned between a rotating driver disk integral with the motor shaft, and a stationary brake disk against which it is spring-loaded. Both the driver and driven disks are included in the flux path of a 36-ohm stationary coil which surrounds the motor shaft extension. Energizing this coil causes the driven disk to be pulled away from the brake disk and into engagement with the revolving driver disk, thus completing the mechanical coupling between the motor and camera. De-energizing the coil releases the driven disk from the driver disk to be spring returned into engagement with the brake disk which arrests its motion. During this displacement, the linear motion of the driven disk is approximately $\frac{1}{64}$ inch which is accommodated by a wide pinion on the driven disk shaft.

A cycle of operation starts midway in the film transporting period (Fig. 5). Following clutch engagement (at A) approximately 30 msec are required to bring the camera up to cine speed which is maintained for 30 msec. The exposure function occurs during this constant speed period (from C to D on the curve). In interval operation, the clutch coil is de-energized and the brake is applied (at E) following the completion of the exposure. The camera decelerates to a stop (at F) in another 30 msec, thus completing the cycle (at G) in a total of 90 msec.

To control this sequence of action, an outside electrical circuit supplies a pulse directly to the clutch coil. After the mechanism has completed one-fourth of a cycle (at B) a cam-driven switch within the camera parallels, and at the same time disconnects, this original pulse circuit. The clutch coil continues to be energized by the internal switch until after shutter closure when it is disconnected and the brake applied. The camera circuitry maintains an open switch in the external pulse circuit until the intervalometer, or other switching device, opens the original triggering circuit. When this circuit opens, the internal switch is closed to restore the original electrical configuration in readiness for the subsequent cycle. This electrical sequence prevents more than one cycle of operation occurring per pulse, regardless of duration, and also stops the camera with its shutter closed.

A push-button brake release located on the camera (Fig. 3) is for manually disengaging the motor to position the intermittent prior to film threading or the shutter for through-the-lens focusing.

An Automax will single-frame at a little more than half its cine frame rate. As an example, a 16 frame/sec camera will single-frame at 10 frame/sec.

Basic cine frame rates of 10, 16 and 24 frame/sec result from selection of standard ratios for the clutch pinion and its mating gear (Fig. 3). On cameras using d-c drive motors, these frame rates can be increased or decreased 15% by the motor governer speed adjustment.

Intermittent Movement

A specially modified Cunningham intermittent movement, of the quick-return claw type, is used (Fig. 4). Dual positioning pins register successive frames to an accuracy of 0.0003 in., resulting in steady projection, prevention of film motion under vibration conditions and

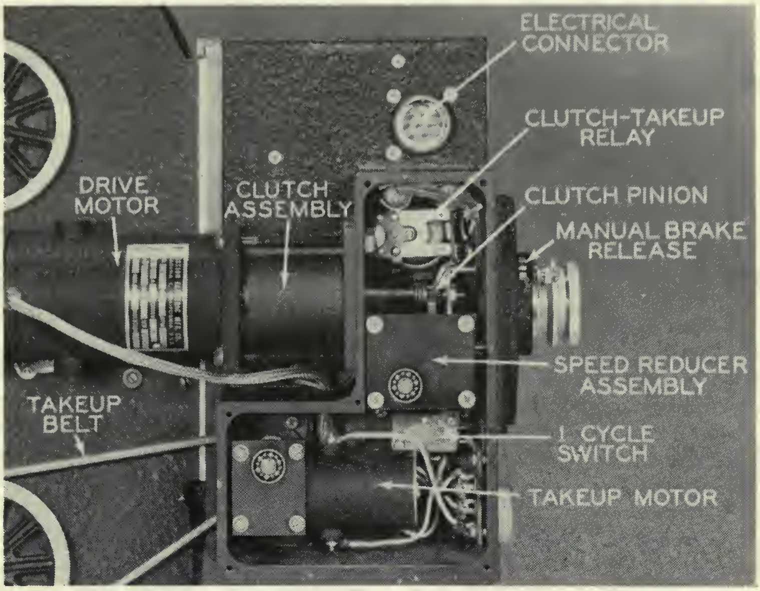


Fig. 3. Camera drive and take-up mechanism.

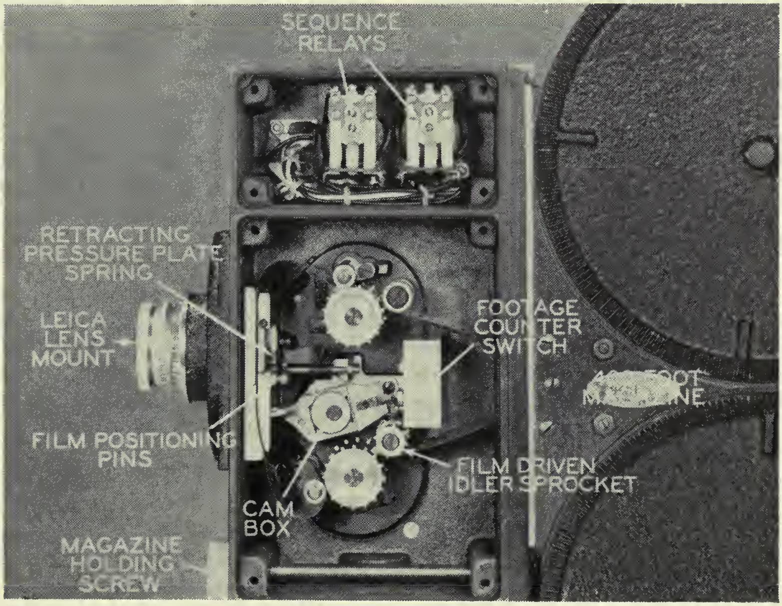


Fig. 4. Intermittent and relay compartment with covers removed.

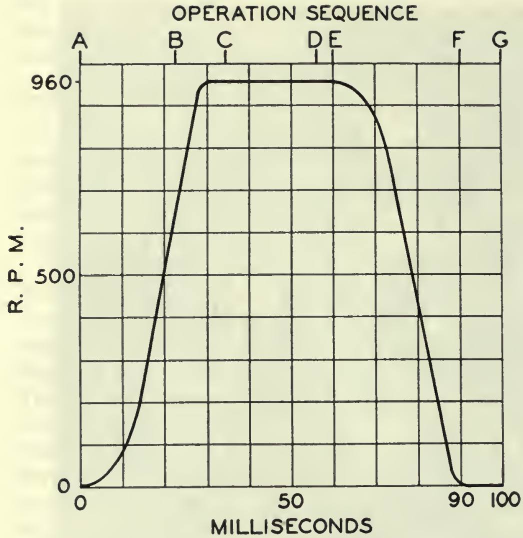


Fig. 5. Curve of one cycle of interval operation at 10-frame/sec rate.

A. Clutch engages.
B. Internal switch closes.
C. Shutter opens.
D. Shutter closes.
E. Brake is applied.
F. Mechanism comes to rest.
G. Start of subsequent cycle.

the accurate framing essential to the use of automatic film reading equipment. Pressure plate retraction during film transporting reduces operating torque requirements, prevents film scratching and emulsion pile-up.

A torque of 2 in-oz at 960 rpm will operate the intermittent. The camera drive applies a torque of 45 in-oz to compensate for the effect of high acceleration.

Film Supply

400-Ft Mitchell magazines are standard. Other types and sizes are adaptable with matching pads. In applications of use under non-accelerated conditions, standard magazines are used without modification. For moderate acceleration and horizontal camera positioning, a micarta lining is substituted for the original fabric lining. Double flanged camera-type reels are advisable for use under highly accelerated conditions.

Film Take-up

A 1/100-hp motor and spring belt drive are used for film take-up (Fig. 3). This motor is energized simultaneously with the clutch coil therefore it operates only as required. Take-up tension on the film cannot overoperate the intermittent movement because of the brake function.

Objectives

Optional Bell & Howell or Leica lens mounts and lens-to-film dimensions permit the use of the full range of either type of lens, including 25-mm wide-angle lenses.

Correlation Switch

A positive pulse, adjustable through the range of from 15° prior to the apex of the shutter opening to 15° after, provides for correlation with associated equipment and/or triggering of flash-tube illumination sources.

Remote Footage Indicator

Remote indication of film supply and camera operation is provided by a film-driven idler (Fig. 4) geared to a switch which momentarily closes a circuit for each foot of film consumed. This circuit, when connected to an

electric 4-place subtractive counter, will show the amount of film remaining and provide visual indication of camera function.

Airborne Performance Data

Acceleration: 10 *G* vertical, 8 *G* parallel to the optical axis and from 3 *G* to 8 *G* parallel to the magazine spindles, depending upon the type of magazine modification.

Vibration: All combinations of frequencies to 100 cycle/sec and amplitudes to 0.02 in. This pertains to mechanical and electrical functions only, as relative motion between camera and subject will naturally affect the photographic function.

Temperature: From +150 F to −10 F. Lower temperatures require special lubrication, not suited to average conditions, or the addition of resistance heaters. When contemplating extremely high- or low-temperature applications, the effect of temperature on film should be considered.

Radio Noise: The camera is completely shielded but a noise filter is recommended for use in the power supply.

Altitude: Standard practices of high-altitude arc suppression are employed.

Note: The above test results were obtained with a 24-v d-c standard camera operating on 22 v d-c.

General Description

The two motors, speed reducers and intermittent cam shaft are ball bearing supported. Dust- and light-tight cover plates on both sides of the cast aluminum case permit rapid inspection. Each component and subassembly — motor, clutch, speed reducer, shutter, take-up drive, intermittent movement, electrical switch and relays — can be independently and readily removed or installed.

The Automax, which weighs 11 lb. without magazine, is $8\frac{3}{4}$ in. high and mounts on its $4\frac{1}{2}$-in. square base. Four positioning pins insure accurate alignment.

Of the several types of cine-interval camera modus operandi tested by this writer and his associates, the electromagnetic clutch in combination with a quality claw type intermittent appears to be the most practical from the standpoints of reliability, simplicity, low maintenance and life expectancy.

Film Reader for Data Analysis

By WALTER M. CLARK and LEE R. RICHARDSON

With the increased use of photographic recorders for military aircraft flight testing, there has been a need for an efficient film reading device to enable rapid evaluation of the recorded data. This paper not only introduces a projector-reader that meets this demand, but also suggests that, with certain modifications, it will be of use to the following: 1. draftsman or engineer, 2. film editor, 3. animator, and 4. rush film reviewer.

NEVER BEFORE has so great a reliance been placed on photography to give analytical data to the aircraft engineer. In order to record reliably and satisfactorily the different components of the test vehicle during flight, expensive and dependable flight recorder cameras have been developed and are in ever increasing use. The compact on-board recorders consisting of from a few to scores of especially modified instruments, as well as the camera, are placed in some accessible area in our modern speedy military aircraft of today.

Aircraft flight photo recording has been briefly mentioned in order to show how much importance is placed on this type of recording. All these elaborate recording devices are used and yet the readers that are generally adapted to interpret this film into usable data were never designed for this purpose and are inadequate especially with the increased length of flight test films.

Presented on October 16, 1951, at the Society's Convention at Hollywood, by Walter M. Clark, Northrop Aircraft, Inc., Hawthorne, Calif., and Lee R. Richardson, Richardson Camera Co., Hollywood, Calif.

The Theory and Analysis Section of the Special Weapons Division of Northrop Aircraft, working under an Air Force contract, approachep this problem by setting about to obtain a device which would efficiently read this film in order to transduce it more quickly into usable data. Design specifications were written which directed Richardson Camera Co., the manufacturer, to incorporate into one unit a reader which would be essentially a projector and screen designed to meet the needs of the data analyst, who is required to read flight test or similar type film one frame at a time or in cine.

Since most of our recorders use 35-mm film, the reader was designed for that size, although it is a simple matter to have interchangeable mechanical panels to permit using 16-mm film. The machine as manufactured to meet these specifications is shown in Fig. 1, with all compartments and doors closed. The cabinet is made of 18 gauge steel measuring 60 in. high, 32 in. deep, and 36 in. wide and is mounted with rubber casters.

Fig. 1. Reader — all closed up.

Components

The screen has a usable area of $18\frac{7}{8}$ in. $\times$ 25 in. centered 48 in. from floor. It is a Stewart vinyl-plastic screen protected from puncture by water-white clear glass in rear of screen (this is to forego any viewing parallax). It is hinged, to allow for conventional projection for a large audience. Figure 2 shows all compartments and doors open.

A cannon connection plug was used between control panel and reader components to allow for connection of a remote control panel (if such is ever required) for use by a lecturer at the reflection screen.

If reader is used in semi-illuminated room, the screen image is easily discernible from any angle up to 70° off axis (Fig. 3). A lamp rheostat is installed to bring the screen brightness to suit the operator.

Since the machine is designed for flight test film, it has a frame aperture size to accommodate maximum usable film area — 47/64 in. by 1 in. with $\frac{3}{32}$-in. radius corners. The lens is a $3\frac{1}{2}$-in. $f/1.9$ Kollmorgen, projecting onto the rear of the screen by means of a system of three front surface mirrors with focus controlled by wheel crank and flexible shaft in the compartment below the control panel. A modified

Fig. 2. Readar — all compartments and doors open.

DeVry projection system is used with a 500-w lamp operating through three sets of three heat absorbing glasses. The lamphouse blower and heat absorbing glasses cool the system, such that if a single frame were to be continuously projected, it would not rise higher in temperature than 152 F.

System of Operation

The criteria for our photo recording called for continuous monitoring in flight, but analysis of only certain sections of the film; therefore, the machine has provisions for cineviewing in variable speed up to 33 frames/sec, as well as stop motion. The operator loads the film into the projection head, turns three lock levers, closes compartment doors and is then ready for projection (Fig. 4).

Cine

He may set controls for cine forward and push down on a variable-speed foot treadle for film viewing. As the operator approaches the section of film that requires critical analysis, he slows the reader down and removes his foot from treadle, stopping machine. He then sets the control panel knob from cine to stop motion. Upon pushing the button on the control panel or pressing the treadle, film will advance one frame

Figure 3. Screen image in partially illuminated room.

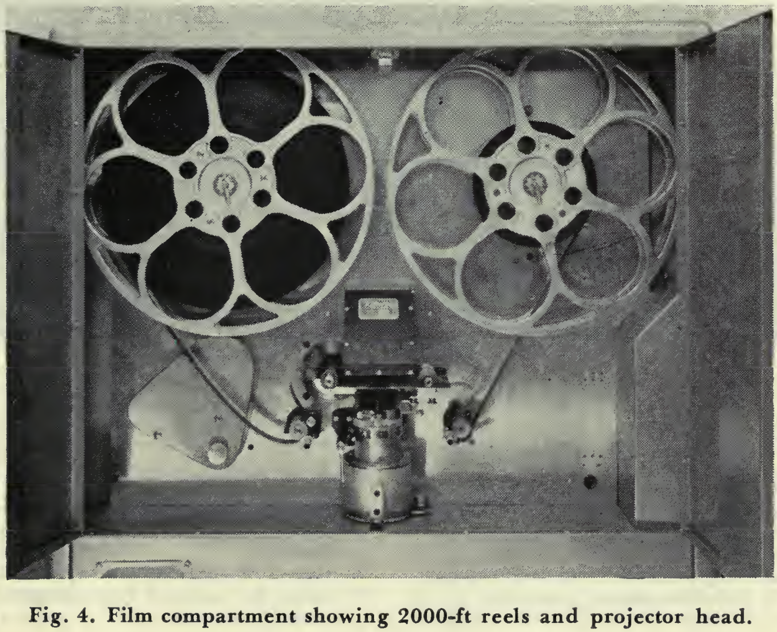


Fig. 4. Film compartment showing 2000-ft reels and projector head.

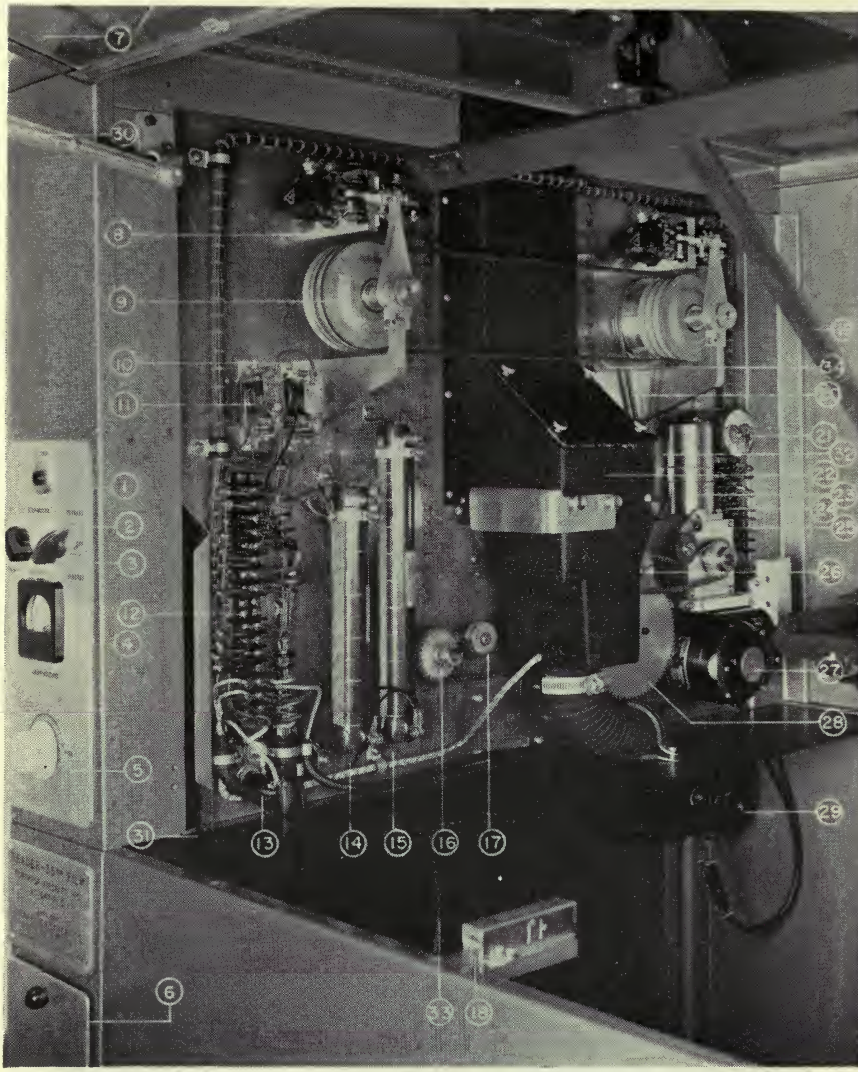


Fig. 5. The mechanical-electrical panel, with top mirror removed.

1. Trip button for single frame
2. Control knob for selection of:
   a. System off
   b. Stop motion
   c. Cine motion
   d. Rewind
3. Control knob for selection of:
   a. System forward (film right to left)
   b. Off (film passage stopped)
   c. System reverse (film left to right)
4. Voltmeter for projection lamp
5. Rheostat for projection lamp
6. Focus control compartment
7. Rear projection screen showing protecting glass (screen in up position)
8. Rewind solenoid for rewind tension kick in
9. Reversible spindle take-up clutch
10. Relay for solenoid trip disconnect in rewind operation

either forward or backward depending on film direction control setting.

Stop Motion

Film may be advanced in stop motion at any rate up to 0.1 sec between pulses and each frame will aline on the screen to within ± 0.080 in. from the previous frame. When film passage is reversed, displacement of 0.750 in. results on the first frame. Since our needs do not require metric-graphic measurements, these displacements cause no concern. However, the reader was designed so that whenever time-space recordings are to be plotted, it could be modified to perform with accurate register by the installation of a register-pin film movement. Also there could be installed an analogue computer system with coordinates measuring wires operating from controls situated immediately below the screen frame.

Rewind

When the film is ready for rewind, the operator takes it out of the projection head, sets the rewind and film direction knobs, and presses on the foot treadle. Film rewinds in either direction 2000 ft in less than two minutes.

Additional Uses

In general, the reader best fits into the needs of the aircraft data analyst. However, it is felt that, since it is portable, it would fit into the needs of the motion picture industry by the addition of a sound head, and could be used as a rush film reviewer on remote location. With the addition of electrically controlled film markers, the motion picture editor would be able to mark a code on the film as he views and reviews the scenes in preparation for cutting.

By redesign of the screen from a vertical to a horizontal position, the animator would find a useful tool. In this configuration also, a drafting table could fit around the screen so that plots and tracings may be made to assist the engineer.

Figure 5 shows the mechanical electrical panel with the top mirror removed. The components are detailed in the legend.

Acknowledgment: The authors wish to acknowledge the sponsorship of this project by the U.S. Air Force. The requestors for the fabrication of this reader were Irving Wieselman and Bill Waddell of the Northrop Aircraft Special Weapons Division.

---

11. Relay for stop motion action (time delay circuit now substituted)
12. Electrical terminal block
13. System fuse receptacle
14 & 15. Resistors for speed control
16. Drive sprocket for film feed
17. Idler
18. Projection screen latch
19. Front surface mirror holder
20. Leather belting for power drive of take-up clutches
21. Capacitor for trip solenoid
22. Lamphouse
23. Housing for stop motion trip solenoid
24. Electrical terminal block
25. Stop motion clutch
26. Intermittent drive sprocket
27. $^1/_8$ hp Bodine motor, for cine and stop motion
28. Large sprocket wheel for feed sprocket assembly
29. Cooling fan for projection lamphouse
30. Hinge bracket for screen holdup
31. System disconnect plug; also remote control unit connection
32. Intermediate pulley wheel for power drive
33. Flexible shaft for focus control
34. Leather belting for take-up clutches

Revised Proposed Standards of Emulsion and Sound Record Positions

MINOR REVISIONS of two American Standards, PH22.15-1946 and PH22.16-1947 ("Emulsion and Sound Record Positions in Camera for 16-Mm Sound Motion Picture Film" and "Emulsion and Sound Record Positions in Projector for Direct Front Projection of 16-Mm Sound Motion Picture Film") were proposed by the Standards Committee in January 1951 and published for trial and comment in the May 1951 *Journal.*

Valuable comments were received and the Standards Committee voted to alter again the two proposals and to republish for another 90-day period of trial and criticism.

The changes made since the May 1951 version consist of altering paragraph 3 in both proposals to specify more definitely the relation between picture and sound and correcting "speed of projection" in paragraph 2.1 of PH22.15 to "rate of exposure."

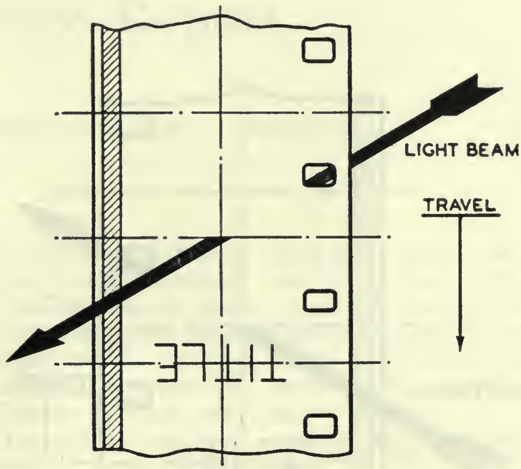
Please forward any comments to Henry Kogel, Staff Engineer, at Society Headquarters by March 1, 1952.

Proposed American Standard

Emulsion and Sound Record Positions in Camera For 16-Millimeter Sound Motion Picture Film

PH22.15
Revision of Z22.15-1946

UDC 778.53



Drawing shows film as seen from inside the camera looking toward the camera lens.

1. Emulsion Position

1.1 The emulsion position in the camera shall be toward the lens, except for special processes.

2. Rate of Frame Exposure

2.1 The rate of exposure shall be 24 frames per second.

3. Distance Between Picture and Sound

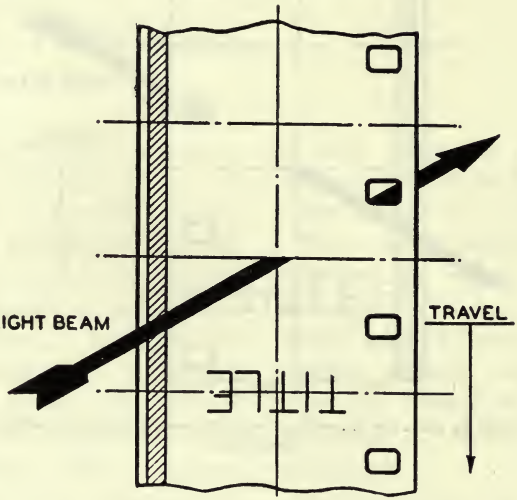
3.1 The film path distance measured in the direction of travel from the center of the picture aperture to the corresponding sound shall be 26 frames ± ½ frame.

NOT APPROVED

Proposed American Standard

Emulsion and Sound Record Positions in Projector for Direct Front Projection of 16-Millimeter Sound Motion Picture Film

PH22.16
Revision of
Z22.16-1947



Drawing shows film as seen from the light-source in the projector.

1. Emulsion Position

1.1 The emulsion position in the projector shall be toward the lens, except for special processes.

2. Rate of Frame Projection

2.1 The speed of projection shall be 24 frames per second.

3. Distance Between Picture and Sound

3.1 The film path distance measured in the direction of travel from the center of the picture aperture to the corresponding sound shall be 26 frames ± ½ frame.

NOT APPROVED

Convention Public Address Committee Report

By E. W. TEMPLIN, Committee Chairman

At the Society's 70th Semiannual Convention a new public address-recording system was used for the first time. This equipment had been engineered and assembled over the past six months by the Eastern Public Address and Recording Committee under the Chairmanship of Harry Braun and was assembled and tested at Society headquarters by Fred Whitney.

The equipment consisted of:

1. Pickup equipment: Two Altec condenser microphones for chairman and speaker; four 633 microphones for floor positions.

2. Mixer. Providing separate adjustment of the preamplifier output of each microphone.

3. Gray Audograph. Operated on output of mixer for recording extemporaneous comments or papers not available in written form at the time of presentation.

4. Power Amplifier and Loudspeakers. For speech reinforcement in the auditorium.

The function of the Public Address Committee was to set up the equipment at the Convention and to operate it at each session excepting those held at remote locations. Vic Allen, the Society's Editor, was on hand at each session to advise the operator about any special requirements, such as recording all of the remarks of one or two speakers who did not have final copies of their papers. A relatively large number of Committee members were appointed so that it would not be necessary for one person to be responsible for more than one session.

Those appointed to the Committee were:

J. A. Beranek, Columbia Broadcasting System
J. P. Corcoran, Twentieth Century-Fox
O. L. Dupy, Metro-Goldwyn-Mayer
J. K. Hilliard, Altec Lansing
J. A. Larsen, Academy Films
F. W. Moran, Universal
J. L. Pettus, RCA
G. E. Sawyer, Sam Goldwyn
W. L. Thayer, Paramount

The sessions were held in the Blossom Room of the Hollywood Roosevelt Hotel except where noted otherwise, below. The persons assigned to the operation of the equipment were as follows:

Monday afternoon: Wm. Schneller, CBS
Monday evening: Frank Moran, Universal
Tuesday morning: Roy Roglin, Westrex
Tuesday afternoon: Phil Thomas, Westrex
Tuesday evening: Sessior held at CBS Studio A. Public address facilities were provided locall› through ar-

rangements made with Messrs. Pangborn and Beranek of CBS.

Wednesday morning: John Stork, Altec

Wednesday afternoon: Allan Wolff, Westrex (equipment moved to Aviation Room)

Thursday morning: Jim Corcoran, Twentieth Century-Fox (equipment moved back to Blossom Room)

Thursday afternoon: Jim Pettus, RCA

Thursday evening: Session held at Republic Studios. Equipment used was the new Stevens Radio Link supplied by Stevens Manufacturing Co. and RYK, Inc. This was operated into public address equipment furnished locally through arrangements with Dan Bloomberg of Republic Studios.

Friday afternoon: J. Valentino, MGM

Friday evening: Session held at Paramount Studio. Public address facilities were furnished locally through arrangements with Dr. C. R. Daily and William Thayer of Paramount.

Each of the above kept a log of notes about identity of discussers, location of discussions on disks, etc. This log proved very valuable when the staff came to transcribe the discussion.

The equipment functioned very satisfactorily throughout the entire period. No difficulties whatever were encountered in the initial setting up of the equipment. The following comments may be useful in connection with subsequent applications of this equipment:

1. The power supply fuse in the power amplifier failed during one of the sessions but was put back in operation again within less than a minute. A $1\frac{1}{2}$-amp slo-blo fuse had been installed. Mr. Hilliard of Altec agreed that a 2-amp or 3-amp slo-blo fuse would give safer protection against inadvertent failure of the fuse without sacrificing protection against short circuits in the amplifier. It is recommended that this change in fuse capacity be made.

2. It was found desirable to locate one of the floor microphones at the mixer operator's position. This was occasionally useful to advise a person speaking from the floor to move to a microphone or to repeat his name and company affiliations, etc., and also to ask a speaker to stop speaking for the interval required to change a record. The rear floor microphone was used for this purpose. In some auditoriums where all four microphones are required on the floor, a fifth microphone should be available for the operator's position.

3. Some operators preferred mixer controls without detents. The present mixer pots could easily be modified if desired.

4. Audio-frequency oscillation occurred in one of the Altec condenser microphones two or three times during the Convention. Mr. Hilliard explained that this was a defect in the vacuum tube used in the preamplifier and that it occurs in a very small percentage of the tubes. When this persists, it is necessary to discard the offending tube.

5. Considerable care was required in the particular rooms used at this Convention to prevent acoustic feedback through the public address system. It was necessary to place the loudspeakers well forward of the nondirectional microphones used at the speaker's and chairman's positions. The quality from these microphones was excellent and many complimentary remarks concerning them were received during the Convention. However, in rooms where acoustic feedback is particularly troublesome, directional microphones at these two positions would reduce the possibility of trouble.

The West Coast Chairman of the Public Address Committee has greatly appreciated the excellent cooperation and assistance received throughout the Convention period from those listed above. Thanks also are due Boyce Nemec and R. T. Van Niman, who by suggestion and assistance made many contributions to the proper functioning of the Public Address Committee.

New Society Emblem—Report of the Special Committee

By L. D. GRIGNON, Committee Chairman

[The following report has been recast in the past tense for *Journal* reading, compared with the form in which it was presented on October 13, 1951, to the Society's Board of Governors.

[Design of a new official Society emblem was proposed at the time of changing the Society's name in January 1950 and the task of producing suggested layouts, then assigned to an Emblem Committee, has now been completed. During the intervening two years, two committees worked diligently on designs that would be suitable for stationery and the *Journal* cover, and symbolize the expanded scope, implied by addition of Television to the Society's name. Since one of three proposals submitted by the second Emblem Committee received approval at the Board of Governors Meeting in Hollywood on October 13, 1951, the story of its evolution is being told here.]

The final Emblem Committee decided to operate as a screening group to reduce the number of potential designs already at hand to five, those to be submitted to the Officers and Managers of the Society's Sections whose votes would further reduce the favored designs to three.

The Committee first voted on a group of ten designs made up of the two most favored designs left over from the work of the earlier Committee and all recent designs not previously considered. Designs had been submitted or proposed by a considerable number of individuals or organizations:

Eastman Kodak Co.,
C. R. Keith, member,
Minnotte-Williams Studios,
Dr. A. N. Goldsmith, member,
Eric Wybrow, member,
Walter Bach, member,
L. D. Grignon, member,
Columbia Broadcasting System,
  Engineering Department,
Reid H. Ray Film Industries,
Naval Photographic Center,
Paramount Pictures Inc.,
  Art Department,
Twentieth Century-Fox Films Corp.,
  Art Department,
Melvin Stewart, art student.

All told, the two Committees examined 37 designs based on 23 distinct ideas. Obviously, there was a substantial coverage of ideas; although with more time other, and perhaps better, designs might be obtainable.

The preferential votes of the members were tallied by three methods and in each case the same five designs were favored. One member considered none of the designs as suitable and another

voted for only the one design which he considered as desirable. The other member made several suggestions for modification of the various designs. It was convenient to execute an obvious modification of one of the favored proposals prior to transmission to the Section Officers, so this was done.

The five designs screened were sent to the Chairmen of the three local sections with the request that all of the officers vote preferentially for three designs and list separately the preference of as many other Society members as might be conveniently obtained. By the same methods of tally as before the three most favored designs, numbered 3, 8 and 9, were chosen. A total of 34 members were also polled and the same three designs were favored.

[The breakdown by different methods of tallying as well as brief suggestions and comments by voters are omitted here.]

There was one particularly significant fact notable in the total vote: except for those few who cast their ballot for less than three designs, every person polled voted in some way for No. 8, which was not true for Nos. 3 and 9.

Of the persons polled, three thought none of the designs of high quality and one suggested we continue the temporary emblem now in use.

In view of the relative standing of the three designs in which No. 9 was always third choice, it was recommended that no further consideration be given that design. Numbers 3 and 8, being very close in the balloting, were both recommended to the Editorial Vice-President and to the Board of Governors as candidates for final selection, if they were deemed suitable. It was suggested that comments as to printability, usefulness and adaptability as a lapel pin be obtained from the *Journal* Editor. The monochrome exhibits which accompanied the report to the Board were rendered in three sizes to enable judging their suitability in small sizes. Also included were exhibits of possible color schemes.

[After discussion following Chairman Grignon's Report, the Board by secret ballot voted the adoption of No. 8 (the one submitted by Melvin Stewart, art student).]

This is it—

SMPTE

Awards

The fields of interest of the Society are served in one way, among others, by an attempt to recognize formally important contributions by individuals. Several awards are conferred annually upon those whose work has been considered significant in their particular fields of interest. Those who were selected during 1951 were presented awards during the Fall Convention of the Society in Hollywood. Their names and awards are listed here.

As has been done in past years there were published earlier this year, in April, the recommendations, citations, and former recipients of the Progress Medal Award, the Samuel L. Warner Memorial Award, and the Journal Award. Recommendations and description of the David Sarnoff Gold Medal Award first presented in 1951 were given in the June *Journal.*

New Fellows of the Society

President Mole formally inducted the following as new Fellows of the Society:

Don M. Alexander, Alexander Film Co., Colorado Springs, Colo.
Clarence S. Ashcraft, C. S. Ashcraft Manufacturing Co., Long Island City, N.Y.
Louis A. Bonn, J. E. Brulatour, Inc., New York
Howard A. Chinn, Columbia Broadcasting System, New York
Alan A. Cook, Wollensak Optical Co., Rochester, N.Y.
Ellis W. D'Arcy, De Vry Corp., Chicago
William C. De Vry, De Vry Corp., Chicago
O. B. Hanson, National Broadcasting Co., New York
William F. Kelley, Motion Picture Research Council, Hollywood
Frank La Grande, Paramount Pictures, New York
Cornelius G. Mayer, RCA International Div., New York
Otto H. Schade, RCA Tube Div., Harrison, N.J.
Hubert J. Schlafly, Twentieth Century-Fox, New York
Vaughn C. Shaner, Eastman Kodak Co., Hollywood
Ethan M. Stifle, Eastman Kodak Co., New York
Lloyd Thompson, The Calvin Co., Kansas City, Mo.

Journal Awards

The Journal Award went to *A. B. Jennings, W. A. Stanton* and *J. P. Weiss* of the Technical Div., Photo Products Dept., E. I. du Pont de Nemours & Co., Inc., Parlin, N.J., for their "Synthetic Color-Forming Binders for Photographic Emulsions," which was published in November 1950.

C. E. Ives and *C. J. Kunz,* of the Eastman Kodak Co., Rochester, N.Y., received honorable mention for their "Simplification of Motion Picture Processing Methods," which appeared in the *Journal* for July 1950.

Honorable mention was conferred on *Pierre Mertz,* of the Bell Telephone Laboratories, New York, for "Perception of Television Random Noise," which appeared in the January 1950 *Journal.*

Special Commendation Award

Each member of the Color Sensitometry Subcommittee of the Color Committee received a scroll in honor of his work on the "Principles of Color Sensitometry" report. This Special Commendation Award was made at the Wednesday night banquet of the

Earl I. Sponable, Past President of the SMPTE, and technical director of 20th Century-Fox, receives two awards—the first man to be so honored by the Society. Awards were made for outstanding contributions to technical advancement of the motion picture art. Participating in the presentation are (from left) Col. Nathan Levinson, Sound Director of Warner Bros., Jack Warner, Production Executive, who presented the annual Samuel L. Warner Memorial Award, Mr. Sponable and Peter Mole, SMPTE President, who conferred the 1951 Progress Medal. Presentations took place at the Wednesday banquet at the Convention.

Convention to *C. F. J. Overhage*, Editor, and his confreres: *H. E. Bragg, L. E. Clark, J. G. Frayne, A. M. Gundelfinger, C. R. Keith, G. C. Misener, H. W. Moyse, S. P. Solow, M. H. Sweet, J. P. Weiss, J. A. Widmer, F. C. Williams* and *H. H. Duerr*. Dr. Duerr as Chairman of the Color Committee authorized and guided preparation of the noteworthy report.

Progress Medal and Samuel L. Warner Memorial Award

Earl I. Sponable, Technical and Research Director of Twentieth Century-Fox and Past-President of the Society, received the Progress Medal and the Samuel L. Warner Memorial Award during the Wednesday night banquet at the Convention, thus becoming the first man to receive the two awards simultaneously. The Warner Award was presented to Mr. Sponable by Col. Nathan Levinson, Sound Director of Warner Bros.

President Peter Mole presented the Progress Medal which the Society conferred "in recognition of outstanding contributions to the technical advancement of the motion picture art, particularly with respect to sound on film, color and large screen television." This formal citation was read by D. B. Joy, Chairman of the Committee which made the selection. All of Mr. Sponable's professional efforts have been channeled in a single broad constructive direction and it was the unanimous view of the Committee that the results of his efforts were far more than adequate qualification because they "resulted in a significant advance in the development of motion picture technology."

Otto H. Shade of the RCA Tube Dept., Harrison, N. J., receives from President Peter Mole the David Sarnoff Gold Medal Award for outstanding achievement in television engineering.

Mr. Sponable first gained prominence shortly after World War I for his development of most of the electrical and mechanical units required for a complete system of sound-on-film recording and reproduction, constituting the basis for the sound motion pictures of today. In 1927, he helped develop the first sound newsreel and, under his supervision, expanded it into a worldwide news coverage medium. He has also been a pioneering leader in the development of equipment and techniques for large-screen theater television.

It was for Mr. Sponable's years of research and development work in the recording of sound-on-film that the Samuel L. Warner Memorial Award was most appropriately presented.

David Sarnoff Gold Medal Award

The David Sarnoff Gold Medal Award, for outstanding technical achievements in the field of television and motion pictures, was first presented this year to Otto H. Schade of the RCA Tube Dept., Harrison, N.J., at the luncheon opening the Convention. Selection of the recipient was made by a committee under chairmanship of Pierre Mertz. Presentation of the award, established in 1951 by the Radio Corporation of America and named in honor of its Board Chairman, was made by SMPTE President Peter Mole.

In appraising Mr. Schade's qualifications the Committee cited him for his recent work in evaluating the gradation, graininess and sharpness in motion picture and television images, and his proposed generalized aperture theory by which the performance of camera lenses, films, television tubes and their circuits may be combined and specified for the first time in objective mathematical terms.

The award was presented to Mr. Schade "for his outstanding accomplishments in the fields of television and motion picture science and engineering, in outlining the potentialities of television and film systems as to fidelity of photography and reproduction of images."

HONORARY MEMBERS

Lee de Forest	A. S. Howell
Edward W. Kellogg	V. K. Zworykin

The distinction of Honorary Membership in the Society is awarded to living pioneers whose basic contributions when examined through the perspective of time represent a substantial forward step in the recorded history of the arts and sciences with which the Society is most concerned.

SMPTE HONOR ROLL

Louis Aimé Augustin Le Prince	Edwin Stanton Porter
William Friese-Greene	Herman A. DeVry
Thomas Alva Edison	Robert W. Paul
George Eastman	Frank H. Richardson
Frederic Eugene Ives	Leon Gaumont
Jean Acme Le Roy	Theodore W. Case
C. Francis Jenkins	Edward B. Craft
Eugene Augustin Lauste	Samuel L. Warner
William Kennedy Laurie Dickson	Louis Lumiere
	Thomas Armat

Elevation to the Honor Roll of the Society is granted to each distinguished pioneer who during his lifetime was awarded Honorary Membership or whose work was recognized subsequently as fully meriting that award.

Engineering Activities

As mentioned in the November issue, six Engineering Committees scheduled meetings at the 70th Convention in Hollywood. Three (High-Speed Photography, Sound and Laboratory Practice) were described in the previous issue and the key aspects of the last three will be outlined below.

Color *1. Lighting for Color Films:* At present, three different types of tungsten bulbs are in use, having color temperatures of 3200 K, 3350 K and 3400 K. The advantages of standardizing on one were enumerated and the related engineering factors discussed. Dr. Duerr, Chairman, questioned whether this project was properly one for Color Committee consideration. In a subsequent discussion with Mr. Kelley of the Research Council, Mr. Bowditch was informed that the subject is receiving active experimental consideration in many studios with insufficient data presently at hand to justify the specification of a single preferred color temperature.

2. Laboratory Processing of Color Film: It was noted that the processing of the color film of the three manufacturers is very similar in many respects, but that the differences are sufficient to provide serious problems for the laboratories where the present-day economics of the situation preclude specializing in just one of the three processes. Recommendations were made that the film manufacturers cooperate to eliminate the differences. This might more appropriately be considered by the Laboratory Practice Committee, but could very well be a joint project of both groups.

Screen Brightness *1. Theater Survey of Screen Brightness:* Ways and means for utilizing the recently completed survey report (published in the September 1951 *Journal*) for improving the viewing conditions in theaters were discussed. Specific recommendations are to be formulated by Wallace Lozier, Chairman, in a brief article for release to the motion picture trade papers.

2. Subcommittee on Meters and Methods of Measurements: Fred Kolb, Chairman of this Subcommittee, submitted an extensive and detailed report for consideration. Upon receiving the Committee's approval, the report will be submitted for *Journal* publication.

3. Recommended Practices for Screen Illumination: The Committee agreed that the theater survey could very well supply the basis for formulating Recommended Practices for illumination of motion picture screens and for the distribution of the illumination. A subcommittee is to be formed to prepare a draft for Committee consideration.

4. Review of Screen Brightness Standard, PH22.39: Based on a recently completed ballot, the Committee decided to revise the present standard by limiting its application to indoor theaters. This recommendation is to be forwarded shortly to the Standards Committee.

Film Dimensions The main discussion revolved about the problems introduced by use of low shrink film. A new standard was proposed based on PH22.34, present cine-negative standard, but with altered values for the pitch dimensions B and L. The appendix to the proposed standard contains a definition of "low shrink film." A letter ballot of the full Committee is the next step.—*Henry Kogel*, Staff Engineer.

Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer

vol. 32, Aug. 1951

Three-Dimension Movies, in Color (p. 306) *R. V. Bernier*

The New Arriflex 16mm Camera (p. 309) *R. Scott*

Shooting News Films for Television (p. 312) *D. L. Conway*

vol. 32, Sept. 1951

Color Correction—What it Means (p. 354) *A. E. Murray*

Duke University Makes Own Teaching Films (p. 356) *E. Porter*

Rangertone Sprocketless Magnetic Tape Recorder (p. 358) *R. H. Ranger*

New All-Purpose Film Leader Benefits TV Film Producers (p. 363) *L. Allen*

Audio Engineering

vol. 35, Oct. 1951

Technique of Record Processing (p. 21) *L. S. Goodfriend*

British Kinematography

vol. 19, Aug. 1951

Television Image Kinematography (p. 36) *W. D. Kemp*

The Screen at the Festival of Britain Telekinema (p. 51) *J. L. Stableford*

vol. 19, Sept. 1951

The Rational Application of Special Processes to Film Production, Pt. I, Introduction to Special Processes (p. 69) *T. W. Howard*; Pt. II, The Choice of Process (p. 73) *A. Junge*

Notes on the Accuracy of Measurements of the Luminance and Illumination of Kinema Screens (p. 77) *H. H. W. Losty and F. S. Hawkins*

The Manufacture of Photographic Chemicals (p. 83)

Canadian Journal of Technology

vol. 29, Sept. 1951

A Continuous Motion Camera for Multiple Exposure of 35mm Film (p. 401) *E. L. R. Webb*

Electronics

vol. 24, Sept. 1951

Crispening Circuit for Color TV (p. 85)

Dot Arresting Improves TV Picture Quality (p. 96) *K. Schlesinger*

vol. 24, Nov. 1951

Television Streaking Test Set (p. 96) *R. K. Seigle*

International Projectionist

vol. 26, Aug. 1951

Stereoscopic Motion Pictures (p. 12) *J. A. Norling*

vol. 26, Oct. 1951

Is Lenticulated Color-Film Practical? (p. 5) *R. A. Mitchell*

Projection in Britain's "Telekinema" (p. 11) *A. Bowen, J. Moir and H. Turner*

Kino-Technik

no. 4, Apr. 1951

Polarisiertes Licht in der Kinotechnik (p. 66) *W. Selle*

Der neue Askania Projektor AP XII (p. 68) *K. Schencke*

no. 5, May 1951

Kino-Technik im Internationalen Blickfeld (p. 87)

Film im Fernsehen (p. 93) *H. Jungfer*

Ein Neues System von Tonwiedergabe analgen (p. 96) *H. Schmidt*

Beschichtung und Regenerierung von Kinofilmen (p. 98) *H. W. Tromnau*

Der Philips FP7-Projektor (p. 100)

no. 6, June 1951

Herstellung von farbigen Bild-Kombinationsaufnahmen nach dem Prinzip der Wandermaske (p. 110) *E. Mutter*

Ein neues System von Tonwiedergabeanlagen (p. 114) *H. Schmidt*

"Aquaflex" die 35-mm-Unterwasser Kamera (p. 116) *W. Beyer*

Störungen bie der Vorführung von Tonfilmen *H. Tümmel*

no. 7, July 1951

Herstellung von farbigen Bild-Kombinationsaufnahmen nach dem Prinzip der Wandermaske (p. 134) *E. Mutter*

no. 8, Aug. 1951

Der neue Super-Parvo mit Spiegelreflexblende (p. 155) *W. Beyer*

Störungen bei der Vorführung von Tonfilmen (p. 161) *D. Braune and H. Tümmel*

Motion Picture Herald

vol. 185, Oct. 13, 1951 (Better Theatres)

Theatre Television in Terms of Motion Picture Projection (p. 12) *G. Gagliardi*

Ballantyne Announces New Model Soundhead and a Screen Tower (p. 38)

The Operation and Maintenance of Theatre Television Equipment, Pt. II, The Picture Tube (p. 41) *A. Nadell*

vol. 185, Nov. 1951 (Better Theatres)

How Today's Lamps Can Make Movies Better Than Ever (p. 21) *G. Gagliardi*

Proceedings of the I.R.E.

vol. 39, Oct. 1951

Alternative Approaches to Color Television (p. 1124) *D. G. Fink*

Color Television of Colorimetry (p. 1135) *W. T. Wintringham*

Subjective Sharpness of Additive Color Pictures (p. 1173) *M. W. Baldwin, Jr.*

Methods Suitable for Television Color Kinescopes (p. 1177) *E. W. Herold*

A Three-Gun Shadow-Mask Color Kinescope (p. 1186) *H. B. Law*

A One-Gun Shadow-Mask Color Kinescope (p. 1194) *R. R. Law*

A 45-Degree Reflection-Type Color Kinescope (p. 1201) *P. K. Weimer and N. Rynn*

A Grid-Controlled Color Kinescope (p. 1212) *S. V. Forgue*

Development and Operation of a Line-Screen Color Kinescope (p. 1218) *D. S. Bond, F. H. Nicoll and D. G. Moore*

Phosphor-Screen Application in Color Kinescopes (p. 1230) *N. S. Freedman and K. M. McLaughlin*

Three-Beam Guns for Color Kinescopes (p. 1236) *H. C. Moodey and D. D. Van-Ormer*

Mechanical Design of Aperture-Mask Tri-color Kinescopes (p. 1241) *B. E. Barnes* and *R. D. Faulkner*

Effects of Screen Tolerances on Operating Characteristics of Aperture-Mask Tri-color Kinescopes (p. 1245) *D. D. Van Ormer and D. C. Ballard*

Deflection and Convergence in Color Kinescopes (p. 1249) *A. W. Friend*

Recent Improvements in Band-Shared Simultaneous Color-Television Systems (p. 1264) *B. D. Loughlin*

Analysis of Dot-Sequential Color Television (p. 1280) *N. Marchand, H. R. Holloway* and *M. Leifer*

Color Television—U.S.A. Standard (p. 1288) *P. C. Goldmark, J. W. Christensen and J. J. Reeves* (also in *Jour. SMPTE, 57:* 336–381, Oct. 1951)

A New Technique for Improving the Sharpness of Television Pictures (p. 1314) *P. C. Goldmark and J. M. Hollywood* (also in *Jour. SMPTE, 57:* 382–396, Oct. '51)

Spectrum Utilization in Color Television (p. 1323) *R. B. Dome*

Observer Reaction to Low-Frequency Interference in Television Pictures (p. 1332) *A. D. Fowler*

Radio & Television News

vol. 46, Nov. 1951

Practical Sound Engineering (p. 72) *H. M. Tremaine*

Tele-Vision Engineering

vol. 2, Sept. 1951

Oscillating Color Sequence in Color TV (p. 18) *R. G. Peters*

Book Reviews

TV Films: How to Produce Them

By The Chalmers Sisters. Published (1951); distributed by American Photography, 421 Fifth Ave. South, Minneapolis 15, Minn. 102 pp. + 4 pp. index. Illustrated. $4\frac{1}{4} \times 6$ in. Price $1.00.

This is not a formal book.

It is a pocket handbook telling the novice "how to do it." As such, its value cannot be disputed, particularly to those who wish to start producing motion pictures in a small way for television, church or similar markets.

Our novice might well purchase this book before he purchases equipment, not that he should necessarily buy the brands recommended but so that he should know what to demand in return for his capital.

Perhaps nowhere else will one find a complete guide in such small size; the chapters range from how to write your own script to how to market your product, from the psychology of directing to a check list for shooting, and how to edit and synchronize sound with picture. The technical error in their explanation of *why* sound is printed 26 frames ahead of sight does not result in misinformation as to what to do in practice.

If you have had professional experience in Hollywood or elsewhere you will not need this book. But if you are new in the game, you will find it stimulating and helpful.—*Harry R. Lubcke*, Consultant, 2443 Creston Way, Hollywood 28, Calif.

The Producer

By Richard Brooks. Published (1951) by Simon and Schuster, Rockefeller Center, New York 20. 337 pp. $5\frac{1}{2} \times 8\frac{1}{8}$ in. Price $3.50.

This is a novel about today in Hollywood and a producer who in his time and place is another Babbitt. The author has been writing and directing motion pictures since World War II and as a novelist he is already known for *The Brick Foxhole* (1945) and *The Boiling Point* (1948).

There is no warning printed at the front of this book that "any resemblance to persons living or dead..."—so, except for what may be strictly autobiographical, the book is intended to depict a composite of the producer in Hollywood. As such, it is successful and valid: it neither paints too much in black nor tries to make a lily-white picture. The choices in gray scale are good and there is transmitted a picture that is lively and colorful without gilded lilies.

If a few scenes and conversations appear flat, the book's overall effect is that of some depth and perspective, a well made picture, well focused and projected. It will light and help bring into focus those nontechnical aspects of motion picture production which are huffed and puffed greatly in the trade and general press. And it will provide a couple of evenings of interesting entertainment.—V.A.

Radio, Television, and Society

By Charles A. Siepmann. Published (1950) by Oxford University Press, 114 Fifth Ave., New York 11. i-vii + 410 pp. $5\frac{1}{2} \times 8\frac{1}{8}$ in. Price $4.75.

This is an absorbing and educative primer (with footnotes), oriented for the United States reader who never knew or does not remember the chaos and static in the nursery of the baby radio industry. And the book offers much for those who are wondering how the newer broadcasting brat, television, will turn out. There is perforce much said about the Federal Communications Commission and its predecessors but even so there is no guarantee that the reader will come to understand every FCC decision, including those on color television.

The author throws much clear light on both the attacks on, and the campaigns on behalf of, advertising in our system of broadcasting. There are thorough comparisons with the British system, and with the Canadian system which stands part way between those of the United States and Great Britain.

The author is well qualified. He was 12 years with the British Broadcasting Corp. for which he was Director of Program Planning and a member of the Corporation's Control Board. A Rocke-

feller Foundation fellowship brought him to the United States in 1937 to study and report on broadcasting over educational stations. In 1939–42 he was a university lecturer and adviser to President Conant of Harvard. During World War II he was with the Office of War Information. In 1945 he served as consultant to the FCC and was one of the authors of its "Blue Book." Since 1946 he has been Professor of Education at New York University and Director of its Film Library. He also completed before this book a commissioned survey of broadcasting in Canada.

This is not a technical book but it will help make less confounded a variety of governmental and business decisions about technical matters.—V.A.

Gas Discharge Lamps

By G. Funke and P. J. Orange. Published (1951) by N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands. Distributed in U.S.A. by Elsevier Publishing Co., 250 Fifth Ave., New York 1. i-xvi + 242 pp. + 28 pp. appendix. 200 illustrations. 6 × 9 in. Price $4.50. English edition.

This is a survey, made by scientists on the staff of the Philips company, of existing types of discharge lamps marketed by that company and a compilation of published work by members of its engineering staff.

The book opens with a good discussion of the fundamental principles of the electrical discharge lamp, some of the underlying reasons for the current-voltage relation found in them, the necessity for special operating equipment, and the general effect of such equipment on the characteristics of the lamp.

Specific discussions cover, for instance, the sodium lamp, for which are given its general physical make-up, its electrical characteristics and the radiation output. Some of the claims, however, made for this lamp as a unit for street lighting have not been substantiated by those interested in street lighting in this country. Two chapters on the characteristics and uses of high-pressure mercury-vapor lamps include a discussion of the effect of this type of light on vision. A compact array of information on the operation and light-giving properties of the fluorescent lamp is fitted into fifty pages, followed by a chapter on beacons and luminous advertisements, and another on stroboscopic and flash tubes.

The appendixes include a list of definitions, and some reference to the works of other engineers in addition to the extended list of papers by Philips engineers already mentioned. The 200 figures and photographic reproductions are well planned. Such books as this, however, would be much easier to read if the generally adopted nomenclature were followed and if the various lamps were referred to either by name or by a description instead of by such designations as Type ML, HO, HP, etc.—*W. E. Forsythe* (Editor, *Physical Tables* of the Smithsonian Institution), 15006 Terrace Road, Cleveland 12, Ohio.

Back Issues of the Journal Available

The issues of Jan. 1930, all of 1931 through 1933; Nov. 1934, and all of 1935 through 1951 are available for any reasonable offer for the lot from: Stanley A. Lukes, 6427 Sheridan Rd., Chicago 26, Ill.

American Standards form the technical foundation for motion pictures around the world. All current standards were listed by subject and by number in the *Journal* Index 1946–1950. Reprint copies of this list, which includes all previous *Journal* references to each standard, are available from Society Headquarters without charge.

Complete sets of all sixty current standards in a heavy three-post binder with the index are $13.50, plus 3% sales tax for purchases within New York City, and are available from Society Headquarters. Single copies of any particular standard must be ordered from the American Standards Association, 70 East 45th St., New York 17, N.Y.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY,

Honorary (**H**) Fellow (**F**) Active (**M**) Associate (**A**) Student (**S**)

Adams, Robert F., University of Buffalo. **Mail:** 1271 Wyoming Ave., Niagara Falls, N.Y. **(S)**

Aller, Lawrence L., Projection Engineer, Universal-International Pictures Co. **Mail:** 15152 Hesby St., Sherman Oaks, Calif. **(A)**

Allred, J. D., Motion Picture Photographer, University of Nebraska. **Mail:** 1025 W. 45 St., Lincoln, Nebr. **(A)**

Andres, Edward A., Sr., Photographic Engineer, USAF, Wright-Patterson Air Force Base. **Mail:** 1300 Carlisle Ave., Dayton 10, Ohio. **(M)**

Anthony, Berkeley F., Training Film Coordinator, Lockheed Aircraft Corp. **Mail:** 7918 Bellingham Ave., North Hollywood, Calif. **(A)**

Austin, Charles, Representative, Mitchell Camera Corp. **Mail:** 1093 Jerome Ave., New York 52, N.Y. **(M)**

Beckett, Robert W., University of Southern California. **Mail:** 2315 S. Flower, Apt. 417, Los Angeles 7, Calif. **(S)**

Bohr, John W. F., Film Director and Editor, Dept. of Education, Film Services. **Mail:** P.O. Box 1592, Pretoria, Union of South Africa. **(A)**

Brault, Andre R., President, Optomechanisms, Inc. **Mail:** 58 Whaleneck Rd., Merrick, L.I., N.Y. **(M)**

Brown, Fordyce M., Physicist, Kenyon Instrument Co., 1345 New York Ave., Huntington Station, N.Y. **(M)**

Byrne, John P., Motion Picture Sensitometrist, Signal Corps Photographic Center. **Mail:** 41–15—48 St., Long Island City 4, N.Y. **(M)**

Cart, William L., Projectionist, United Paramount, Tenarken Division. **Mail:** 1212 W. Fourth St., Owensboro, Ky. **(A)**

Clarke, William R., University of Southern California. **Mail:** 427 S. Alexandria Ave., Los Angeles 5, Calif. **(S)**

Courtney, Larry, University of Southern California. **Mail:** 1209½ W. 30 St., Los Angeles 7, Calif. **(S)**

Engel, H. Bob, General Sales Manager, Golde Manufacturing Co. **Mail:** 3318 Lake Shore Dr., Chicago, Ill. **(A)**

Folks, Charles C., Motion Picture Technician, Dept. of State, Foreign Service. **Mail:** APO 205, c/o Postmaster, New York, N.Y. **(A)**

Gilbert, Ellis A., Motion Picture Camera Manufacturing, Berndt-Bach, Inc. **Mail:** 1830 N. Cherokee Ave., Hollywood 28, Calif. **(A)**

Glenn, James A., Manager, Special Effects Dept., National Broadcasting Co. **Mail:** 34–40—79 St., Jackson Heights, N.Y. **(M)**

Greenberg, Wilfred, SRT Television Studios. **Mail:** 14 Grafton St., Brooklyn 12, N.Y. **(S)**

Gums, John R., Service Manager, Swank Motion Pictures, Inc. **Mail:** 4169A Shenandoah, St. Louis 10, Mo. **(M)**

Hauver, Clifford C., Photographic Technologist, U.S. Naval Research Laboratory. **Mail:** 4003 Oliver St., Hyattsville, Md. **(A)**

Hirsch, Sidney, School of Radio Technique. **Mail:** Box 4, Lumberville, Bucks County, Pa. **(S)**

Hogan, Alsede W., Electronic Engineer, American Radio & Television Corp. **Mail:** Box 1082, Brownsville, Tex. **(A)**

Joseph, George E., School of Radio Technique. **Mail:** 16 Christopher St., New York 14, N.Y. **(S)**

Kral, Karel Bedrich, Director, Manager, Griffin Film Enterprises, Ltd. **Mail:** Griffin Lodge, Betsham, Nr. Gravesend, Kent, England. **(M)**

Kruttschnitt, Pell, University of Southern California. **Mail:** 1745 N. Gramercy Pl., Hollywood 28, Calif. **(S)**

Lakebrink, Robert T., Teacher-Laboratory Chief, American Television Institute of Technology. **Mail:** 4529 N. Malden St., Chicago 40, Ill. **(A)**

Leahy, J. V., Contact Engineer, Film Recording, RCA Victor Div., 411 Fifth Ave., New York 18, N.Y. **(A)**

Levonian, Edward, University of Southern California. **Mail:** 1533 Fourth Ave., Los Angeles 19, Calif. **(S)**

Lindsay, Raymond A., Camera Research, Jerry Fairbanks, Inc. **Mail:** 2031 Argyle Ave., Hollywood 28, Calif. **(M)**

LoPresti, Paul J., Sound Recordist, Reeves Sound Studios, Inc. **Mail:** 2763 Reservoir Ave., Bronx, N.Y. **(A)**

Lownsbery, 1st Lt. Robert, Director of Television, Signal Corps Mobile TV Detachment. **Mail:** Officers Mail Rm., Bldg. T-521, Fort Monmouth, N.J. **(A)**

Lytle, John, Producer, 16-Mm Sound Motion Pictures, Slides, Slide Films. **Mail:** 410 W. First St., Dayton 2, Ohio. **(A)**

Maurer, Edwin A., National Schools. **Mail:** 13809 S. E. Division, Portland 66, Ore. **(S)**

Metzger, Charles H., Photographer. **Mail:** 7038 East Ave., Cincinnati 36, Ohio. **(M)**

Milira, Ken, University of Southern California. **Mail:** 1122 W. 37 Dr., Los Angeles 7, Calif. **(S)**

Murtough, William L., Broadcast Engineer, Columbia Broadcasting System. **Mail:** 255-11—75 Ave., Glen Oaks, N.Y. **(A)**

Ogura, Juzo, Managing Director, D. Nagase & Co., Ltd., 7 Itachibori Minamidori 1 Chome, Osaka, Japan. **(A)**

Otto, Roy S., Projection Engineer, Universal-International Studios. **Mail:** Box 255, Universal City, Calif. **(A)**

Parlan, Stanley, Television Film Director, National Broadcasting Co. **Mail:** 24 E. 82 St., New York 28, N.Y. **(A)**

Polister, Richard C., University of Southern California. **Mail:** 1138 Browning Blvd., Los Angeles, Calif. **(S)**

Pourciau, Louis L., Engineer, General Precision Laboratory. **Mail:** 13 Manville La., Pleasantville, N.Y. **(M)**

Roberts, Fred G., Jr., President and Salesman, Training Aids, Inc. **Mail:** 4429 Sherman Oaks Cir., Sherman Oaks, Calif. **(A)**

Sager, Clifton G., 16-Mm Film Producer. **Mail:** Route #1, Grafton, Wis. **(M)**

Sandbo, Robert, Herbert Kerkow, Inc. **Mail:** 40 W. 96 St., New York 25, N.Y. **(A)**

Schreiber, E. H., Staff Engineer, Pacific Telephone & Telegraph Co., Rm. 858, 740 S. Olive St., Los Angeles 55, Calif. **(A)**

Serdy, Henry W., Motion Picture Photographer, Allis-Chalmers Co. **Mail:** 1500 S. 57 St., West Allis 14, Wis. **(A)**

Shamberg, Kurt D., New Inst. for Film and Television. **Mail:** 80-50 Forest Parkway, Woodhaven, L.I., N.Y. **(S)**

Strang, John, SRT Television Studios. **Mail:** 353 W. 57 St., New York 19, N.Y. **(S)**

Tubbs, G. Christian, SRT Television Studios. **Mail:** 251 W. 74 St., New York 23, N.Y. **(S)**

Unk, Jaap M., Professor, Electrical Engineering, Delft University. **Mail:** S Gravelandsche Weg So., Hilversum, The Netherlands. **(A)**

Waver, Frank H., University of Southern California. **Mail:** 1220 Fifth Ave., Los Angeles, Calif. **(S)**

Wilkinson, Frank H., Sound Technician, Universal Studio. **Mail:** 4956 Laurel Canyon Blvd., North Hollywood, Calif. **(A)**

Winkler, Lew, Television Maintenance Engineer, National Broadcasting Co. **Mail:** 11444 Oxnard St., North Hollywood, Calif. **(A)**

Wolber, John R., Jr., University of Southern California. **Mail:** 6117 Glen Alder, Hollywood 28, Calif. **(S)**

Yeager, J. Harry, Motion Picture Cameraman and Projectionist, St. Louis Amusement Co. **Mail:** 1026 Sylvan Pl., Kirkwood 22, Mo. **(A)**

Zurek, Val C., Sr., Supervisor, Motion Picture Laboratory, General Film Laboratory. **Mail:** 4355 E. Outer Dr., Detroit 34, Mich. **(A)**

CHANGES IN GRADE

Abramson, Albert, Teacher, Los Angeles City School. **Mail:** 3441 W. Second St., Los Angeles 4, Calif. **(S)** to **(A)**

Frost, Floyd A., Cinematographer, U.S. Government. **Mail:** Box 220, China Lake, Calif. **(S)** to **(A)**

George, Samuel R., TV Technician, RCA Victor Div. **Mail:** 1026 N. Crescent Heights Blvd., Hollywood 46, Calif. **(S)** to **(A)**

Gillette, Frank N., Development Engineer, General Precision Laboratory. **Mail:** Manville La., Pleasantville, N.Y. **(A)** to **(M)**

Harwood, Erwin G., Secretary and Treasurer, National Cine Equipment, Inc. **Mail:** 514 West End Ave., New York 24, N.Y. **(A)** to **(M)**

Jalas, Clarence A., Partner, Essannay Electric Manufacturing Co. **Mail:** 188 W. Randolph St., Chicago, Ill. **(A)** to **(M)**

Long, Charles R., District Engineer, Motion Picture and Television Lighting, Westinghouse Lamp Div., 600 St. Paul Ave., Los Angeles 17, Calif. **(A)** to **(M)**

Mann, Gordon P., Manager, Ansco Technical Service Dept. **Mail:** E. Maine Rd., R.D. #1, Johnson City, N.Y. **(A)** to **(M)**

Noble, Joseph V., Consultant, Motion Picture Film Counselors. **Mail:** 107 Tuscan Rd., Maplewood, N.J. **(A)** to **(M)**

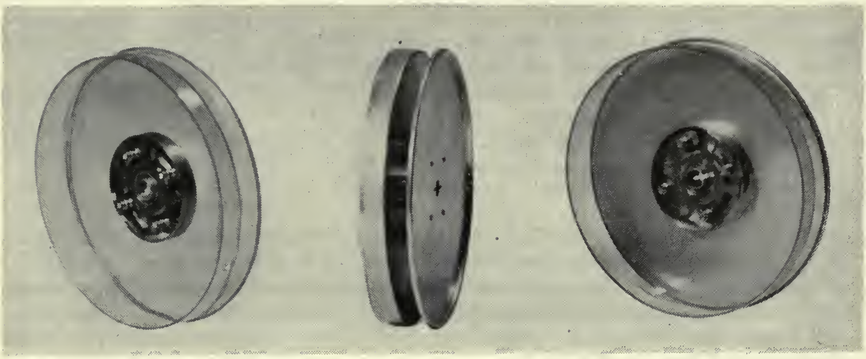
Opochinsky, David, Vice-President, Titra Film Laboratories, Inc. **Mail:** 320 W. 76 St., New York 23, N.Y. **(A)** to **(M)**

Pettus, J. L., Mechanical Design Engineer, RCA Victor Div. **Mail:** 1560 N. Vine St., Hollywood, Calif. **(A)** to **(M)**

Sherwood, Larry, Vice-President, The Calvin Co., 1105 Truman Rd., Kansas City, Mo. **(A)** to **(M)**

New Products

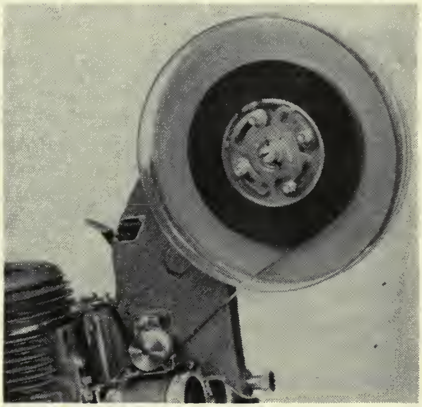
Further information about these items can be obtained from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.



A combination reel and film can is made in one unit called the Reel-Can by the manufacturers, Thalhammer Specialties, 10219 Eldora Ave., Sunland, Calif.

Made of metal, it is designed to save metal, money and time. There is a special film-threader with spring clamp to attach film to reel. The lid is constructed so that when it is fixed by spring lock and pins to the base with rim upwards the rim serves as the side of the reel. When the lid is inverted, with rim down, and fastened by the same spring lock and pins, it becomes the lid of the storage can.

A 200-ft, 8-mm Reel-Can costs $1.50 postpaid. Other sizes in both 8-mm and 16-mm are planned.



The 1952 edition of the RCA Pocket Reference Book has been announced by the RCA Tube Dept., Harrison, N.J. It is also available from RCA distributors.

This year's is a revised edition, expanded to include information on products introduced during the past year, so that it now contains complete product listings and data on the characteristics, interchangeability and socket requirements of more than 450 RCA receiving tubes. including kinescopes, with similar data on 75 dry batteries. Other sections of the book include: a selection guide for power, cathode-ray, photo and special tubes; a section on radio and television test equipment and trouble shooting; and a description of available technical literature on the various RCA products.

Papers Presented
at the Hollywood Convention, October 15–19

MONDAY AFTERNOON

Otto H. Schade, RCA Tube Dept., Harrison, N.J., "Requirements for a Theater Television System Giving Detail Contrast Equivalent to 35-Mm Motion Pictures."

F. N. Gillette, General Precision Laboratory, Pleasantville, N.Y., "A Direct-Projection System for Theater Television."

Blair Foulds and E. A. Hungerford, Jr., General Precision Laboratory, Pleasantville, N.Y., "A Television Camera Adaptable to Theater Network Use."

L. T. Sachtleben, RCA Victor Division, Camden, N.J., "An Ultra-High-Speed Optical System for Theater Television."

P. J. Herbst, J. M. Brumbaugh and R. O. Drew, RCA Victor Division, Camden, N.J., "Factors Affecting Quality of Kine Recordings."

MONDAY EVENING

A. G. Jensen, R. E. Graham and C. F. Mattke, Bell Telephone Laboratories, Murray Hill, N.J., "A Continuous Motion Picture Projector for Use in Television Film Scanning."

A. S. Quiroga and C. G. Pierce, American Broadcasting Co., Hollywood, Calif., "Motion Picture-Type Lighting in Television."

A. D. Fowler, Bell Telephone Laboratories, New York, "Observer Reaction to Video Crosstalk in Television Pictures."

G. C. Higgins and L. A. Jones, Eastman Kodak Co., Rochester, N.Y., "A Method of Making Objective Measurements Which Correlate With Subjective Picture Sharpness."

TUESDAY MORNING

B. B. Jackson and F. M. Ashbrook, U.S. Naval Ordnance Test Station, Inyokern, Calif., "Time Coordination of Photographic Instrumentation on Missile Range."

M. G. Holland and D. E. Dunn, North American Aviation, Los Angeles, Calif., "High-Speed Photography and High-Speed Aircraft."

E. C. Barkofsky, U.S. Naval Ordnance Test Station, Inyokern, Calif., "Multiple-Image Silhouette Photography for Aeroballistics Research."

J. H. Waddell, Wollensak Optical Co., Rochester, N.Y., "High-Speed Photography of Moving Objects."

D. H. Peterson, Peterson & Pease, Glendale, Calif., "The Rotoscope as a High-Speed Camera Accessory."

John Kudar, Consultant, Hollywood, Calif., "Optical Problems in High-Speed Camera Design."

TUESDAY AFTERNOON

R. O. Painter, General Motors, Proving Ground Section, Milford, Mich., "Techniques for Effective High-Speed Photography and Analysis."

Walter M. Clark, Northrop Aircraft, Inc., Hawthorne, Calif., and Lee R. Richardson, Richardson Camera Co., Hollywood, Calif., "Film Reader for Data Analysis."

A. P. Neyhart, Guild Laboratories, Manhattan Beach, Calif., "Cine-Interval Recording Camera."

G. J. Badgley and W. R. Fraser, U.S. Naval Photographic Center, Washington, D.C., "New Automatic Film-Threading Motion Picture Camera."

H. V. Hilker, U.S. Naval Ordnance Test Station, Inyokern, Calif., "High-Speed Camera Calibration."

R. K. Bucher, U.S. Naval Ordnance Test Station, Inyokern, Calif., "New Power Supply for the Fastax Camera."

TUESDAY EVENING

Harry Lubcke, Consulting Engineer, Hollywood, Calif., "Color Television Reproducers."

R. S. O'Brien, Columbia Broadcasting System, New York, "Conversion of Monochrome Studio Equipment for Color Standards."

D. E. Foster, Hazeltine Research of California, "Some Fundamental Considerations in Color Television."

W. E. Evans, Stanford Research Inst., Stanford, Calif., "Color Television — Order or Chaos."

WEDNESDAY MORNING

Lt. Lowell O. Orr, Navy Motion Picture Exchange, Brooklyn, N.Y., and Philip M. Cowett, Bureau of Ships, Navy Dept., Washington, D.C., "Desirable Characteristics of 16-Mm Entertainment Film for Naval Use."

C. R. Carpenter, Pennsylvania State College, "A Scientific Approach to Informational-Instructional Film Production and Utilization."

M. A. Kerr, Dept. of Physics, Wheaton College, Wheaton, Ill., "High Fidelity Film Reproduction of What?"

J. K. Hilliard, Altec Lansing Corp., Beverly Hills, Calif., "Application Notes on the Use of 35-Mm and 16-Mm Film in Television and Armed Forces."

Norwood Simmons, *Moderator*, "Emulsion Position of 16-Mm Positives," a panel discussion with 11 participants from the floor and on the panel.

WEDNESDAY AFTERNOON

A. C. Robertson, Eastman Kodak Co., Rochester, N.Y., "Dimensions of 16-Mm Film in Exchanges."

R. L. Sutton, K. B. Curtis and Lloyd Thompson, The Calvin Co., Kansas City, Mo., "Prints from 16-Mm Originals."

J. G. Streiffert, Eastman Kodak Co., Rochester, N.Y., "The Radial-Tooth Variable-Pitch Sprocket."

A. L. Holcomb, Westrex Corp., Hollywood, Calif., "Film-Spool Drive With Torque Motors."

J. W. Kaylor and A. V. Tesek, Cinecolor Corp., Burbank, Calif., "The Cinecolor Multi-Layer Color Developing Machine."

C. R. Dupree, Signal Corps Photographic Center, Long Island City, N.Y., "The Application of Magnetic Clutches for Conversion of Sprocket-Drive Developing Machines to Friction Drive."

THURSDAY MORNING

Kurt Singer and H. C. Ward, RCA Victor Division, Hollywood, Calif., "A Technical Solution of Magnetic Recording Cost Reduction."

Kurt Singer and J. L. Pettus, RCA Victor Division, Hollywood, Calif., "A Building Block Approach to Magnetic Recording Equipment Design."

Marvin Camras, Armour Research Foundation, Chicago, Ill., "A New Magnetic Recording Head."

Edward Schmidt, Reeves Soundcraft Corp., New York, "Manufacture of Striped and Full-Width Professional Magnetic Films."

L. L. Ryder, Paramount Pictures Corp., Hollywood, Calif., "Use of Magnetic Stripe Track."

L. L. Ryder and B. H. Denney, Paramount Pictures Corp., Hollywood, Calif., "Standard Placement of 35-Mm Magnetic Track."

THURSDAY AFTERNOON

C. E. Hittle, RCA Victor Division, Hollywood, Calif., "Twin-Drum Film-Drive Filter System for Magnetic Recorder-Reproducer."

C. C. Davis, J. G. Frayne and E. W. Templin, Westrex Corp., Hollywood, Calif., "A Multichannel Magnetic Film Recording and Reproducing Unit."

G. A. Del Valle and F. L. Putzrath, RCA Victor Division, Camden, N.J., "Optical-Magnetic 16-Mm Sound Projector."

H. W. Pangborn, Columbia Broadcasting System, Hollywood, Calif., "The Use of $\frac{1}{4}$-In. Magnetic Tape for Kinescope Sound Rebroadcast Purposes."

H. E. Haynes, RCA Victor Division, Camden, N.J., "A New Principle for Electronic Volume Compression."

THURSDAY EVENING

H. H. Duerr (Committee Chairman), Ansco, Binghamton, N.Y., "Color Committee Report."

H. H. Duerr, Ansco, Binghamton, N.Y., "The Ansco Color Negative-Positive Process for Motion Pictures."

R. H. Ray, Reid H. Ray Film Industries, Inc., St. Paul, Minn., "Use of Ansco Type 843 35-Mm Color Film in Commercial Production."

C. R. Anderson, N. H. Groet, C. A. Horton and D. M. Zwick, Eastman Kodak Co., Rochester, N.Y., "An Intermediate Positive-Internegative System for Color Motion Picture Photography."

A. M. Gundelfinger, Cinecolor Corp., Burbank, Calif., "Supercinecolor Process."

Bela Gaspar, Gasparcolor, Inc., Hollywood, Calif., "Gaspar Color Process and Demonstration."

S. P. Solow, Consolidated Film Industries, Hollywood, Calif., "The Trucolor Process."

FRIDAY AFTERNOON

L. D. Grignon, Twentieth Century-Fox Films, Beverly Hills, Calif., "Recent Improvements in Silencing Engine-Driven Generators."

G. L. Dimmick and M. E. Widdop, RCA Victor Division, Camden, N.J., "A Heat Transmitting Mirror."

W. W. Lozier, National Carbon Co., Fostoria, Ohio, and F. T. Bowditch, National Carbon Co., Cleveland, Ohio, "Carbon Arcs for Motion Picture Studio Lighting."

L. L. Ryder and C. A. Hisserich, Paramount Pictures Corp., Hollywood, Calif., "New Remote-Control Light-Weight Incandescent Lighting Equipment."

R. T. Van Niman, "Report on Lead Sulfide Photo-Electric Cell."

W. W. Lozier (Committee Chairman), National Carbon Company, Fostoria, Ohio, "Screen Brightness Committee Report."

FRIDAY EVENING

L. D. Grignon, Twentieth Century-Fox Films, Beverly Hills, Calif., "Preliminary Report of Special Committee on Picture Flicker."

I. M. Terwilliger, Inspacian Enterprises, Hollywood, Calif., "Depth Dimension Accomplishments by Inspacian Systems."

Norman McLaren, The National Film Board of Canada, Ottawa, Ont., Canada, "Stereographic Animation."

Raymond Spottiswoode, Harrow-on-the-Hill, Middlesex, England, "Production and Projection of Three-Dimensional Film."

John G. Stott, Du-Art Film Laboratories, New York, "The Tri-Art Color Laboratory."

M. L. Gunzburg, Natural Vision Corp., Hollywood, Calif., "Natural Vision Three-Dimension."

INDEX TO SUBJECTS

July — December 1951 • Volume 57

Lighting

THEATER TELEVISION

American Standards — by numbers

INDEX TO AUTHORS

July — December 1951 · Volume 57